MARCH 2, 1951

THE ENGINEER

A Seven-Day Journal

The Institution of Electrical Engineers

THE annual dinner of the Institution of Electrical Engineers was held at Grosvenor House, London, on Thursday, February 22nd. Professor E. D. Adrian, President of the Royal Society, who proposed the toast of "The Institution of Electrical Engineers," said that the growth in the size and importance of the Institution was indicated by the fact that its membership had doubled itself in fifteen years. In his response, Sir Archibald J. Gill, President of the Institution, referred to some of the problems involved in the expansion of membership. In 1909, when the I.E.E. came to its present home, Savoy Place, there were 6000 members; now there were 37,000, and this total was growing at the rate of about 1500 a year. It was clear that, by the time the existing lease expired in 1984, the present premises would no longer provide adequate accommodation. One of the major tasks ahead of the Institution was to ensure that engineers were at least as well trained as their opposite numbers in other parts of the world. To do that would not be easy, bearing in mind the estimate that the present number of graduates was estimated to be at least 10 per cent less than the number required by industry. There was also a shortage of well-trained technicians. Professor E. B. Moullin, Immediate Past-President of the Institution, proposed the toast of "Our Guests," and the response was shared by Mr. Hugh Lyon, Director of the Public Schools Appointments Bureau, and by Sir Henry Self, Deputy Chairman of the British Electricity Authority. Mr. Lyon agreed with Sir Archibald Gill that there were good opportunities, matched by a growing need, for some of the best young men in the country to enter industry and commerce. At the same time, it was very desirable that many of the best young men should stay at school until the age of 18 or 18½ years to fit themselves for responsibility by learning something of the arts of human relationships. Mr. Lyon therefore felt that industrialists must devise some means of allowing recruits to the profession of engineering to remain at school to the age of about 18 years. The difficulties of finding suitable recruits were, of course, accentuated by the fact that the present age group of 15 to 18 years was numerically small.

The Carton and Box Industry

THE importance of packaging, especially for the export trade, has been emphasised in various ways in recent times. The engineering and other industries will therefore find a good deal of interesting and useful information in the report of a specialist team, organised by the Anglo-American Council on Productivity, which spent some weeks in the U.S.A. last year investigating the rigid boxes and cartons trades. Like other specialist teams which have visited the U.S.A., this team was impressed by the high rate of productivity. The tour included visits to carton and box-making plants of all sizes and the report says that American labour was found, in some instances, to be giving as much as 50 to 70 per cent more production per man-hour than British labour. The team noted that machines were running faster and that operators were able to keep them fed, giving a high yield of work and maintaining output throughout an eight-hour day without fatigue. As in this country, the American box and carton industry is staffed largely by female labour. The team concluded that production in the American industry was assisted by specialisation. "While in normal times," its report notes, "one would say that Britain does not want to become standardised, in times of economic crisis such as the country finds itself in to-day, it would appear that specialisation of production would go a long way to reduce costs and give greater productivity." Another interesting observation made in the report relates to safety measures. The team says that, although there is a good drive in America for safety precautions, it found, in general, that the guarding of machinery was in no way comparable with that in the United Kingdom. Among its recommendations the team suggests that, as the British box trade is badly in need of new modern plant it should be enabled to purchase some of the American plant available at short delivery dates, so that the industry can re-equip itself and increase its output.

Steel Foundry Research

AN agreement has been reached between the British Iron and Steel Research Association and the research and development division of the British Steel Founders' Association, whereby the latter organisation now becomes responsible for the co-operative research requirements of the steel foundry industry. Work on steel castings, which has been initiated by B.I.S.R.A., is to be continued under the direction of the British Steel Founders' Association, at whose disposal certain facilities and funds have been placed by B.I.S.R.A. The combined programme of work undertaken by the research and development division of the B.S.F.A. can therefore proceed without interruption. In making this agreement it is recognised that the steel castings division of B.I.S.R.A. has successfully supervised and greatly extended research work on steel castings since the steel castings research committee of the Iron and Steel Institute ceased to function five years ago, but it is also fully realised that the time is now appropriate for the steel foundry industry to take over and support its research work in a manner best suited to its own particular needs.

Lloyd's Register Launch Returns

THIS week Lloyd's Register of Shipping has issued its "Annual Summary of Merchant Ships Launched in the World During 1950." In Great Britain and Northern Ireland 275 ships of 1,324,570 tons were launched during the year, the total including 124 steamers of 527,758 tons and 151 motorships of 796,812 tons. It represented 37·9 per cent of world output. A table gives tonnages for each year since 1932 and another gives the figures for the principal countries, noting at the same time the fluctuations as compared with 1949. Ships exceeding 15,000 tons are individually listed and the increased number and size of oil tankers are reflected in the increase, in the average size of ships launched, from 3960 tons in 1949 to 4820 tons in 1950. Excluding ships of less than 1000 tons, fifty-eight oil tankers, of 614,003 tons, were launched, the total including nine steamers of 122,973 tons and forty-nine motorships of 491,030 tons and representing 46·6 per cent of the total output. Of the ships launched, eighty-five of 440,651 tons (33·3 per cent) are for registration abroad. Ships launched abroad, excluding China, Poland, and Russia, totalled 738 of 2,168,306 tons, made up of 186 steamers of 846,849 tons and 552 motorships of 1,321,457 tons. The tonnages launched by the leading countries are tabulated and ships exceeding 15,000 tons are named. Oil tankers of more than 1000 tons totalled ninety-one ships, of 965,244 tons, including thirty steamers of 450,117 tons and sixty-one motorships of 515,127 tons and representing 44·5 per cent of the total tonnage. A series of paragraphs gives the launching particulars for the principal countries abroad. World output for 1950 reached 3,492,876 tons, an increase of 361,071 tons over 1949. This is partly due to the inclusion of the figures for Germany. Motorships represent 61 per cent of world production compared with 56 per cent in 1949 and steamers buring oil fuel total about 1,275,000 tons. Oil tankers of 1000 tons and upwards amounted to 149 ships of 1,579,247 tons, representing 45·5 per cent of the total output; 64 per cent are motorships, a figure which is 11 per cent more than in 1949. Of the world total of ships launched, 431 ships of 2,132,738 tons (61·06 per cent) were being built under the survey of the Society.

The Late Sir Arthur Street, G.C.B.

WE have noted with regret the death of Sir Arthur Street, which occurred suddenly in London last Saturday, February 24th, at the comparatively early age of fifty-eight. He had been deputy chairman of the National Coal Board since March, 1946. Sir Arthur was born at Cowes, Isle of Wight, and was educated at Sandown County School and King's College, London. After military service in the first World War, during which he was mentioned in dispatches and awarded the M.C., he was appointed Principal Private Secretary to the Minister of Agriculture and Fisheries. Sir Arthur subsequently went to the Admiralty, but returned to the Ministry of Agriculture as a Principal in 1922, where he remained until 1938. In that year, he was appointed Deputy Under-Secretary of State for Air, and a year later he became Permanent Under-Secretary of State at the Air Ministry, a post which he occupied with distinction throughout the second World War. At the end of the war, Sir Arthur, who had been knighted in 1938, was seconded as Permanent Secretary to the Control Commission for Germany and Austria. But a few months later Sir Arthur was recalled from that post to take up the deputy chairmanship of the National Coal Board.

Record Transatlantic Flight

ALL records for a Transatlantic flight were broken on Wednesday, February 21st, when an English Electric "Canberra B 2" tactical bomber completed the trip in 4 h 40 min at an average speed of more than 445 miles an hour. The machine took off from Aldergrove, Northern Ireland, at 12.43 p.m. and landed at Gander airfield at 5.53 p.m. G.M.T. The flight was made against heavy head winds and, for most of it, the machine flew at an altitude of over 40,000ft. It should also be noted that this was the first non-stop Transatlantic flight to be made by a jet bomber. The machine was piloted by Squadron Leader A. E. Callard, and the crew of three wore experimental clothing which has been specially developed for high-speed, high-altitude flying. Shortly before the flight was made, one of the wings of the "Canberra" was holed when it hit a seagull in flight, and a fine piece of repair work by mechanics was completed in record time in preparing the machine for the flight. The "Canberra," it will be remembered, gave impressive demonstrations at the last two S.B.A.C. shows at Farnborough, and the Mark I machine was described in some detail in our issue of December 2, 1949.

Productivity in British Industry*

No. XVIII—PRODUCTIVITY IN AGRICULTURE

By CORNELIUS DAVIES, D.Sc. (London), M.I.B.A.E.†

ABOUT half the food we consume in this country is produced from our own soil. Something like 31 million acres are under the plough, growing crops either for direct human consumption, or indirect in the way of grass and other animal feeding stuffs. In addition, there are 17 million acres of what the farmer calls rough grazing, that is, mountain and other pasture land which, for various reasons, it is not possible or economical to cultivate. The labour force engaged in agriculture numbers approximately 1,250,000. That, it must be remembered, takes no account of the many ancillary trades, such as corn and fertiliser merchants, manufacturers and machinery dealers and repairers, those concerned with the marketing of farm produce, and so on.

Farmers have been called on to increase their production, and this, in the main, has to be done by getting more from the land already under cultivation. Schemes are afoot to bring derelict and semi-derelict parts of the country into a fit state so that something better than bracken, heather and similar useless vegetation can be grown. This is not an easy task, because the very nature of much of the marginal land calls for the expenditure of a great deal of money to clear bush and scrub, plough the rough areas, supply lime and fertilisers, drain water-logged soil, and build roads and cottages. But whatever is done to marginal land in the future does not immediately concern those farmers who are operating in more favourable parts of the country, and it is with them that this article is concerned.

Increased productivity can be attained in a number of ways, depending on the type of farming undertaken, on the soil and topography of the farm, and on the capital available. Mechanisation plays an important part in modern husbandry, and will be discussed more fully, but before going into further details some of the biological factors involved are touched on to give a more complete picture.

Biological Factors

Plant breeders are tirelessly seeking new and better strains of farm crops. New varieties of wheat and barley are introduced from time to time. They have various characteristics, such as resistance to fungus diseases, ability to stand up in stormy weather, which subsequently makes harvesting easier, better milling and bread-making qualities, or, in the case of barley, having certain properties which are sought by brewers. Improved strains of grasses and clovers are brought to the attention of farmers through the agricultural Press and the National Agricultural Advisory Service. Some have drought-resisting qualities; others have been specially bred for certain types of soil where difficulty has been experienced in getting good herbage to grow. Then, again, higher yields per acre or improved protein content might be the goal aimed at by the plant breeder.

In the realm of livestock, too, farmers are ever seeking to improve cattle and pig breeds to get quicker maturing and better quality animals. Dairy cow yields have gone steadily upwards. The 1000-gallon-a-year cow, not many years ago something in the nature of a phenomenon, is quite an ordinary beast nowadays. This has been achieved by selection and breeding from high yielding stock. Scientific feeding, too, and instructed management, also contribute to greater milk flow. In breeding, the sire is a most important factor in getting the desired characteristics. A bull coming from a line of high milkers is likely to transmit high milk-yielding propensities to his female progeny; but such bulls command large prices and there is a definite limit to the offspring they can beget by normal mating. But with the advent of artificial insemination a much greater number of cows can be served. Artificial insemination will have far-reaching effects on the improvement of cattle in the future.

Fertilisers play a most important part in the growing of corn, root and herbage crops, and the scientific application of chemical fertilisers is a most potent influence in the production of good crops. Research work on plant nutrients—the sort of manure to use, how and when to apply and just where it should be placed relative to the crop roots—is going on all the time. A large store of knowledge and experience about fertilisers exists, knowledge available to every farmer for the asking. All soils do not need the same nutrients for a given crop, because some are richer, or poorer, in phosphates, lime, potash or one of the other plant foods.

Soil Cultivation

The actual tilling of the soil to prepare the right sort of seed bed is an art rather than a science, and rules which suit one field do not necessarily lead to the formation of a good tilth elsewhere; climatic conditions, topography, previous cropping and the very soil itself vary from place to place; so knowledge and experience have to be brought into play. It is a bold man who says he knows all about cultivation, but the wise man benefits from the learning of others. The same crop cannot be grown successfully in the same field year after year. To get the best results rotations are necessary. At one time rather rigid rotations were practised, but these had to be abandoned to a great extent during the war, and much in the way of crop husbandry was learnt as a result. To-day the farmer follows a more elastic system as a general rule, and he and his land benefit from the modern findings of agricultural science.

At one time the preservation of ancient grasslands was normal practice; nowadays, old pastures are ploughed up, other crops are grown for a spell, and then perhaps the field is put down to grass again for a number of years. But when that is done, better varieties of herbage are sown than those which grew there in the past. This is known as ley farming, the ley being the temporary herbage crop. Increased fertility and better husbandry follow this process of "going round the farm with the plough." Anything to do with the land is naturally very much governed by the weather. Very dry and hard ground cannot easily be ploughed; if an arable field is wet and sodden serious damage to the crops, and even to the soil itself, will be done if heavy cultivating implements go on to it. In Britain the climate is such that some much-needed operation might be delayed, and, because nature does not wait on man's convenience, when conditions do become favourable the work must be done quickly. That is where power farming, or mechanisation, plays such an important part.

Mechanised Farming

Farming cannot be judged by ordinary industrial standards, because of this tremendously variable element, the weather. That must always be remembered when attempting to decide whether those who follow the ancient craft of agriculture are efficient or not. It must be borne in mind, too, that very few farming operations can be mechanised as are factory processes. In the factory a production line can be planned, and, providing supplies of raw materials and other things are fed to that line—all more or less under man's control—production will go on as planned. But the cycles of nature are beyond human control, and they cannot be relied upon to be constant. That point needs no elaboration, but the uninitiated might not fully appreciate that the machinery used on a farm, even on a highly mechanised one, has, with very few exceptions, quite a short seasonal use. Apart from a limited number of appliances, such, for instance, as milking machines, most farm implements can only work for a few weeks in the year. Ploughing is done in the autumn, sowing and planting in the spring, and harvesting only when there are crops to harvest.

This seasonal use of farm machinery means that the farmer and his men are always having to plan ahead to get a particular implement ready for the job as the season approaches. It may entail no more than oiling and greasing, but often worn parts have to be renewed and broken portions mended, which means that farmers have to be handy with mechanic's tools. The average farm worker is a pretty good all-round craftsman; nevertheless, mechanical equipment has come on to our farms in such numbers during the past decade that the skills necessary to get the most out of it have lagged behind somewhat, a factor which leads to high repair bills at times. Large-scale and quick changes in any walk of life generally find most of the community lacking the requisite instruction to derive the fullest benefits from the changes, and it takes some time for the educational services to satisfy the needs. That is certainly true so far as mechanisation of agriculture is concerned. Fortunately, those bodies and individuals concerned with this matter, and possessing foresight, have been loud and insistent in their demands for educational facilities to be provided. Slowly, the various authorities are organising classes and courses where tractor drivers, machine operatives, farm

* No. I, "An Introductory Survey," by B. White, appeared February 17, 1950; No. II, "The Threshold of Productivity," by F. A. Martin, March 3rd; No. III, "High Productivity and Production Costs," by Sir Claude Gibb and Gordon M. Baker, March 17th; No. IV, "Standardisation in the Aircraft Industry," by E. C. Bowyer, March 31st; No. V, "Restrictive Practices," by Arthur Woodburn, April 21st; No. VI, "Research for Productivity," by Dr. D. F. Galloway, May 19th; No. VII, "Consequences of Simplification," by W. D. King and H. Sherburn, June 30th; No. VIII, "Works Extensions," by C. K. F. Hague, July 28th and August 4th; No. IX, "Mechanical Handling," by F. Garner and A. Siddall, August 11th and 18th; No. X, "The Importance of the Craftsman," by F. V. Everard, September 1st; No. XI, "Productivity in the Smaller Engineering Works," by Antony Vickers, September 15th; No. XII, "Productivity in Civil Engineering," by Lieut.-Colonel C. M. Norrie, September 29th; No. XIII, "The Measurement of Productivity," by L. H. C. Tippett, October 13th; No. XIV, "The Contribution of the Machine Tool Industry," by J. B. S. Gabriel, October 20th; No. XV, "Safety in Industry," by Sir Alfred Herbert, October 27th and November 3rd; No. XVI, "Factors Affecting Production," by E. W. Steele and W. Symes, December 22nd; No. XVII, "Productivity, Authority and Responsibility," by W. B. D. Brown, February 2, 1951.

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mechanics and more highly qualified agricultural engineers can receive the training so vitally necessary to render our mechanised agriculture efficient in every sense of the word. Seasonal use of implements and machines poses another problem for the farmer, which is the housing of the equipment for all the months of the year when it is idle. The economics of storing idle machinery in a factory for the major part of the year need no stressing; they also play an important part in the business of farming where buildings are wanted for livestock, seeds, fertilisers, grain, hay, straw and other commodities.

The tractor has taken the place of the horse for the majority of field operations, yet 1000 hours' work a year from a tractor is considered to be quite a high output. A combined harvester-thresher, a machine which goes into a standing field of ripe corn and cuts and threshes and separates the grain from the chaff and straw, might complete the task allotted to it in a matter of a fortnight or three weeks. The same applies to ploughs, seeding drills, manure distributors, mowing machines and a host of other agricultural implements. These machines all cost money, some of them a great deal of money; so the farmer is faced with the problem of having capital locked up in mechanical equipment which has a short seasonal use, and which is of little, if any, use for out-of-season jobs.

The majority of the farms in this country are small, as the following figures show:—

Size of farm, acres	Number of farms
5 to 99	216,000
100 to 149	31,000
150 to 299	34,000
300 to 499	8,000
500 to 699	2,000
700 to 999	897
1000 and over	432

It will be seen that something like 74 per cent of the agricultural holdings are under 100 acres. In other words, the food grown in this country comes mainly from small farms. The man working on a small farm cannot justify large-scale mechanisation, any more than the owners of a factory which turns out only a few products in the course of a year could economically tool up to the same extent as a large concern working on mass-production lines.

Despite the smallness of the average farm in Britain our agriculture is mechanised to a greater extent than most other countries in the world. Accurate statistics are not readily available, but an approximate enough idea of the position is gained by studying the tractor strength in various countries, as shown here:

Country	Acres (cereals, potatoes and roots) per tractor
New Zealand	36
Great Britain	50
U.S.A.	109
Holland	200
Canada	238
Australia	322

What surprises many people is that the United Kingdom has a greater density of tractors per unit area of cultivated land than the United States of America. Most of this increase has taken place since 1939, and the periodical farm machinery census indicates that we have not yet reached the peak. Tractors numbered about 50,000 before the last war; now there are over 250,000, and there has been a corresponding increase in tractor ploughs and all the other implements for use behind the tractor. Then, in the last decade, combined harvesters, pick-up baling machines, various kinds of green forage harvesting machines, tractor transport trailers and potato and sugar beet harvesters, practically never seen here ten years ago, have come on to the land in hundreds and in some cases in thousands.

The tractor has revolutionised agriculture. Before its introduction, or, perhaps, to be more accurate, before it was used to the extent that it is now, the horse was the chief source of power for most of the pulling and transport work on the farm. The horse eats food grown on land where food for human consumption can be grown. The horse tires, must be stabled and watered and groomed and fed every day of the week and every week of the year. Of course, the tractor has to be fed and groomed and stabled to some extent, but when not working it needs no constant attention.

The modern tractor is not only an excellent and a tireless source of tractive power for hauling the implements and vehicles the farmer uses in his business, but, with the power pulley, it drives stationary pumps, grinding mills, chaff cutters and similar machines; with the power take-off it supplies the necessary motion to the mechanism of things like corn binders, mowers, dung spreaders and other machines which have to be hauled over the land and provided with turning power as well. In recent years, the tractor has been fitted with yet another device, a hydraulic lift for raising the working parts of a machine from the ground when turning at the headlands. This lift is a great saver of human effort and a speeder up of the particular operation to which it is applied. Some of the implements so mounted on a tractor take time to fit—often longer than the sales literature leads the farmer to believe!—and it is a matter for each individual to decide whether the advantages of mounted implements are or are not offset by this factor.

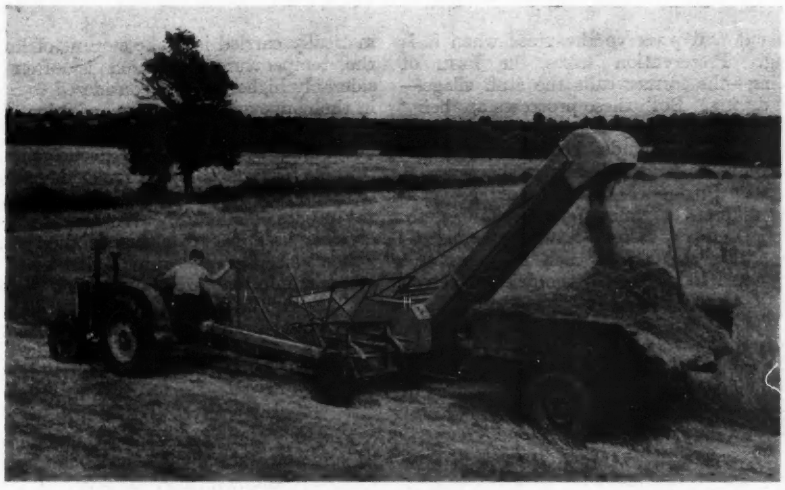
The tractor was the most potent influence in the drive, during the war, to produce more food, when our food was under the serious U-boat threat, and now still to produce more food, but this time to reduce our dollar expenditure. Ploughing is the heaviest common operation on the farm, requiring, on the average, a mean sustained pull of about 600 lb to turn a single furrow. That is a good load for a pair of strong draught horses. Should the going be heavier, three or even four horses would have to be hitched to the single-furrow plough, and a good day's work would be done if the team turned over 1 acre of soil. Lightweight tractors can easily pull a two-furrow plough, and the majority of tractors at work on the land to-day are designed to haul three- and even four-furrow ploughs. Ploughing is the basic farming operation, and the increase in the rate of ploughing, brought about by the tractor, is a major contributing factor to increased productivity in the farming industry.

The story is the same for subsequent cultivations, such as harrowing, deep stirring of the soil and consolidating it by rolling; wider implements, implements with greater penetration, and fewer stops to rest the horses—and the man—enable the farmer not only to get his cultivations done in less time, but to manage conveniently larger acreages with the same labour force.

A further, incidental, advantage accrues when ploughing with a tractor, and that is the prevention of "plough plan," or the hard impermeable layer of soil formed, just below the depth of ploughing, by the sliding action, year after year, of the plough, always working to the same depth. With horses it is well-nigh impossible to get the plough in more deeply to burst through this hard layer, whereas a tractor nearly always has power in reserve, so that the plough can be set to penetrate sufficiently deeply to break up any "pan" formed during previous years.

Farm Implements and Machinery

Corn and seed drilling machines and artificial manure distributors have been increased in working width to suit the greater power of the tractor, or, if for various reasons it is not convenient to have these machines of a width, in one unit, to provide an economical load for the tractor, they are ganged—that is, two or three separate drills or distributors are coupled together to give a width equal to the sum of the separate widths. In this way, advantage can be taken of favourable seeding weather—sometimes short in duration—and the critical job done rapidly when conditions are most suitable, which is one of the main tenets of good crop husbandry.



FORAGE HARVESTER

Something like 9,000,000 tons of potatoes a year are grown in England and Wales. This heavy crop is produced on about 1,300,000 acres. The work to prepare the land, set the seed potatoes, apply fertiliser and ridge up the soil over the seed is quite considerable, and can involve four separate operations, after the basic cultivation is done. The modern tractor-mounted potato planter will open three ridges, deposit the seed, apply a measured quantity of fertiliser, just where it is wanted, and then split the ridges, covering the tubers in the desired manner at the

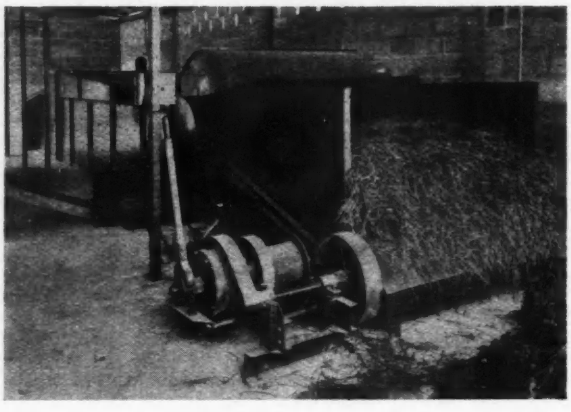
rate of 7 or 8 acres a day, and with a labour force of two or three men.

There is a shortage of animal feeding stuffs, without which beef, mutton, milk, butter, cheese, pork and bacon cannot be produced. Many of these feeding stuffs were imported before the war; now we have to rely on our own farms to grow a sufficiency. Starchy food is not so scarce, but proteins are, and the oil-cake and similar "concentrates" previously bought from overseas cannot be produced here. Fortunately, there exists in our grassland a huge supply of protein. The trouble is that grass is rich in protein only in the early stages of growth, but all the pigs and sheep and beasts have to be fed throughout the year, during the major part of which there is but little grass, or its protein content is low. The solution is to cut and preserve the grass when it is young. Preservation takes the form of pickling—the farmer calls the stuff silage—or of drying. Both these processes are being used to an increasing extent, but both make heavy power demands, because large tonnages have to be handled in a short period of time. During the last five or six years many different designs of green-crop cutters, loaders and harvesters have appeared to help gather the protein-rich herbages and carry them to the silo or the drier. We are only at the beginning of this campaign to get the utmost value from our pastures. Hardly a month goes by without a new kind of forage harvester making its appearance. To stimulate inventors and manufacturers to their best endeavours the Royal Agricultural Society of England held a national competition last autumn at which several designs of grass harvesting machines were thoroughly tried and tested.

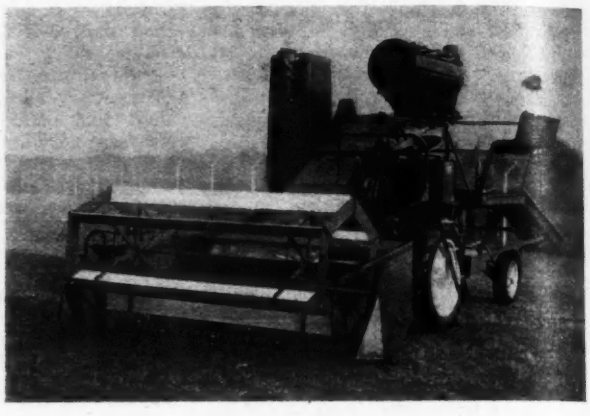
Grass driers, ranging in size and complexity from the small ¼-ton-an-hour portable farm outfit up to the large factory-like plant costing thousands of pounds, have been coming on to the market in steadily mounting numbers. The moisture content of green grass is high, averaging something like 85 per cent, which means that in a ton of grass there are nearly 2000 lb of water, the majority of which has to be evaporated by heat. That is a simple enough thing for an engineer to do, but the farmer is not so much concerned with the mere evaporation of water as with the preservation of the feeding value of the herbage he has been to so much trouble to grow.

The simplest form of grass drier consists of a perforated tray holding a layer of herbage through which hot air is passed. Such a plant naturally has a small capacity and all the crop has to be man-handled. Further, its thermal efficiency cannot be anything but low. An improved version of drier of this type has two trays so arranged to allow the partly saturated hot air coming from one tray to evaporate some of the moisture contained in the other tray. The general design of this plant is such that the mechanical as well as the thermal efficiency is reasonably good. Most grass driers offered to farmers are constructed on the conveyor principle and the green stuff passes through in a continuous stream, being subjected to the drying process in various ways. Output and efficiency are nearly always higher on these designs than on tray driers.

A few driers of foreign origin have grass-chopping units as part of the outfit, and the small lengths of green material are pneumatically carried into the current of hot air, the temperature of which is often considerably higher than is considered to be safe in the conveyor or tray type of drier. These imported plants, some of which are now being made over here under licence, are more suitable for large co-operative drying schemes than for the farmer whose protein requirements are moderate. Whatever form of drier is used the resulting product can be either baled, ground into a fine meal in a hammer mill, or, after pulverising, it can be put through a cubing machine. This last process inevitably adds to the cost, but the convenience of handling and feeding cubed dried grass is great.



GRASS DRIER



SELF-PROPELLED COMBINE HARVESTER

GRAIN HARVESTING

Probably the most spectacular machine to come on the land during the past decade is the combined harvester-thresher. Certainly it has received more attention in the daily Press than any other aspect of mechanisation. Corn growers have invested in combines—as these machines are called—to an extent not even the most ardent advocate of mechanisation would have predicted ten years ago. Before the war there were barely a dozen combines in the country; the latest information indicates that there are now over 10,000, and these can deal with approximately 1¼ million acres of cereal crops.

Some combines are entirely tractor operated; others are pulled by a tractor, but have a separate engine to drive them. The self-propelled machine has an engine powerful enough both to propel it through the corn and to operate all the mechanism. With one of these a single man can go into a 10-acre field of ripe corn and harvest it in a day—that is, the combine will cut, thresh, separate grain from straw and chaff, and deliver the grain into bags ready for carting away. The machine will cost about £1000, but the job is done for under £2 an acre when conditions are favourable. All the corn grown in this country cannot be harvested in this way because there is an economic limit beyond which the capital outlay on a combine is not warranted. No rigid rule can be laid down to determine what acreage justifies the purchase of a combine—or, for that matter, any other large and expensive machine. Nevertheless, British farmers are using combines to an increasing extent in their efforts to step up the productivity of their holdings.

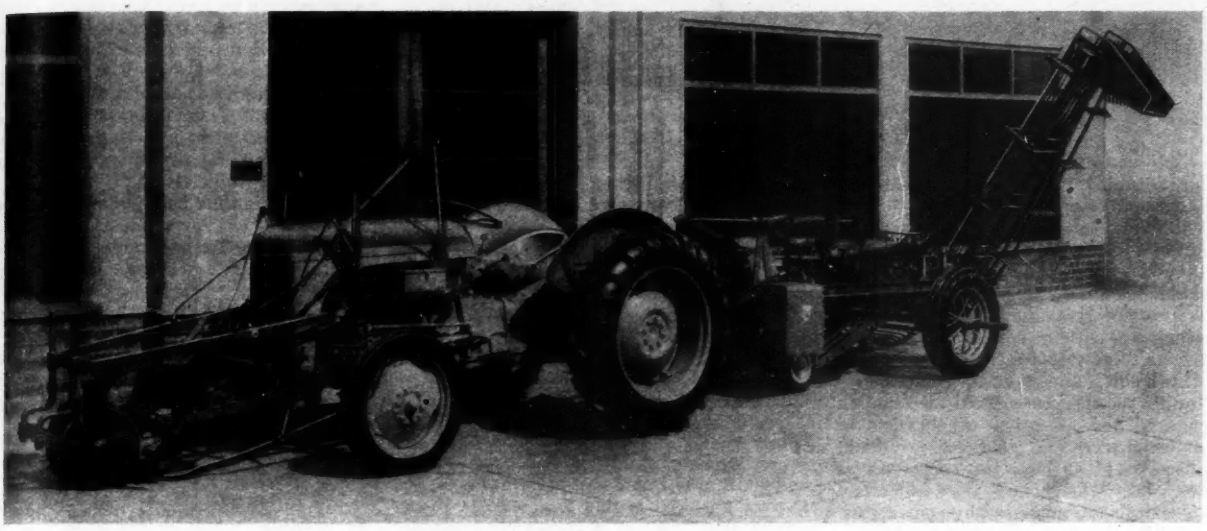
The introduction of the combine has brought in its train problems of handling and storing bulk grain which did not exist when the ancient practice of stacking unthreshed sheaves in ricks or barns was followed. Grain driers of all descriptions, conveyors and elevators—pneumatic and mechanical—storage bins and dressers are now being installed on farms at a rate difficult to compute.

When corn is cut and bundled with the reaper and binder the sheaves are stooked in the field where they are dried and matured by sun and wind. The combine-harvester threshes the grain as it goes, and often the loose grain is too moist for safe storage in sacks or bins. To reduce this moisture to limits which ensure that the grain will not heat and go mouldy recourse is had to grain driers. In all but a few favoured districts a farmer is unwise if he decides to harvest his wheat and barley with a combine should he have no drying facilities within reach. A great deal of research and investigation has been conducted in recent years on this matter of farm grain drying. The problem has not been finally resolved to everyone's satisfaction yet, but there has emerged a set of rules which, when followed, will ensure that grain is not spoiled even when it is harvested with a combine in a damp condition and is stored in bulk for long periods.

Grain is living material and the farmer has to see that the milling or bread-making qualities are not destroyed during the drying process. The principle used on a farm drier is to pass the grain, in a predetermined layer, slowly through the drier and to direct a current of hot air in and around the mass as it moves along on a conveyor, or falls by gravity. The temperature of the air is critical, if the grain is not to be spoilt, and so is the rate of drying. Output cannot be speeded up by raising the temperature and the speed of movement. To prevent sweating after drying the grain is subjected to a cooling blast of air before leaving the

drying plant. To cater for the needs of those farmers who do not handle sufficient corn to justify the outlay on a full-scale drier the National Institute of Agricultural Engineering has evolved two less expensive drying outfits. One of these is the warm-air-ventilated bin, which will extract a certain amount of moisture and at the same time store the grain in bulk. The other outfit is a sack drier, simple enough in design—apart from an oil-fired heater—which can be built by farm labour, and will deal with forty 1 cwt sacks at a time.

Bulk-handling and storing loose grain coming from the combine-harvester are something comparatively new for British farmers, and to retain their bargaining powers with merchants who buy the corn, farmers have had to tackle the problems of handling and storing. Bins or silos now form a necessary part of many farms. These bins are made of concrete, brick, metal and sometimes, when obtainable, of wood. Elevators and conveyors are often complementary to storage bins, and, of course, they considerably reduce man-handling of the grain. A dresser, to winnow out chaff, weed seeds and other unwanted stuff, is a necessary adjunct for the man who harvests his corn with a combine. Pneumatic conveyors are often used; these having the merit of being able not only to elevate and carry grain horizontally, but also to convey it around corners with a minimum of mechanical devices. The accurate determination of the moisture content of combined grain is a matter of importance, and to achieve it a variety of precision moisture testers have been put on the market. Armed with these instruments, corn growers have an accurate means of ascertaining whether their grain is in a fit state to store or not.



SUGAR BEET TOPPER AND HARVESTER

Root Harvesting

Corn growing, therefore, in all its stages, has been satisfactorily mechanised. The same cannot be said, however, about the two main root crops—potatoes and sugar beet. The planting of the seed potatoes has already been mentioned. This is a comparatively simple and easy task compared with the job of lifting the crop. As every gardener knows, the edible tubers grow under the surface and have to be lifted out of the ground, shaken from the roots and bine, and separated from soil, clods and stones. An average crop is about 7 tons to the acre, which means that power must be available to lift that weight, as well as to loosen and sieve out the unwanted materials. In the process the potatoes must not be bruised, otherwise their keeping and selling qualities are impaired.

Until recently potato growers have been content to lift the crop to the surface of the ground with a machine called a spinner, leaving the potatoes to be picked up by hand. A gang of up to twenty pickers is needed to keep up with the spinner, and it is the cost and, at times, the scarcity of that labour force which has led so many to attempt to make a complete potato harvester. Development has been rapid in late years and there are now machines on the market which, while they are not completely automatic, do harvest the potatoes with considerably fewer men. These machines are necessarily large and expensive and are, therefore, not economical for the smaller growers to own.

The greatest problem facing an inventor who attempts to design a potato harvester is the extremely variable nature of the soil. A prototype will put up an excellent performance in a given field, under certain climatic conditions, but in another field with a different sort of soil, or even in the same field when it is wet or full of weeds, it will fail miserably. The engineer who designs a machine to work in a factory, where all the conditions are calculable, has an easy task compared with the man who sets out to produce a potato harvester capable of operating satisfactorily anywhere. Nevertheless, the good work goes on.

Spinners and complete harvesters are not the only machines used to lift potatoes. The elevator digger is something between these two, in that its labour requirements are less than for the spinner, but the tubers have to be loaded by hand. Nearly 10,000 of these are at work, compared with 60,000 spinners, and a mere 500 harvesters. It is doubtful if there were 100 elevator diggers in use on the outbreak of war, and certainly no harvesters at all, which is further proof that farmers are not as conservative and reluctant to take to modern methods as is sometimes said.

The mechanisation of sugar beet harvesting is handicapped in similar ways to potatoes, yet more progress has been made in the evolution of beet harvesting machines, and there is no doubt that before very long labour-saving appliances to suit the wide variety of soils in which sugar beet is grown will not only be available, but will be used. Perhaps it would have been more logical to mention another aspect of beet growing before discussing root harvesting; this is the hand work involved in singling out the young seedlings during the early stages of growth. The seed is sown in rows with a drill, more being deposited than will be allowed to come to maturity. This is because no machine has yet been made which can put but one seed just where it is required, and because germination or survival of that one seed cannot be assured. With sugar beet there is another thing to add to the difficulties; that is the peculiarity of the so-called beet seed. The seed, in fact, consists of a cluster of two or more true seeds, each capable of producing a seedling. So at an early stage of growth the young plants must be thinned out to the distance apart which experience has shown is the best for the maximum growth and highest yield.

The production of a single-seed precision drill is not impossible of attainment; in fact, many people are working on that; but until there is mono-germ beet seed such a drill would not solve the singling problem. A great deal is being done in that direction, too. Plant breeders are attempting to breed a mono-germ seed, and much work has been done with existing seeds to reduce the proportion of doubles and trebles growing out of each husk. Shearing the seed, pelleting it so that the single germ is encased in a little sphere of suitable material, and grinding the irregular-shaped husk to reduce the number of viable germs within and also make it more regular in shape and thus easier to handle in a precision drill, are the methods researchers have been trying. The rubbing or decorticating process is being attended with a greater measure of success than the others. Much of this work is being done at the agricultural experimental station at Sprowston in Norfolk, and the investigators there are reasonably confident that a reduction in singling labour of 40 or 50 per cent is within sight. When it is realised that this singling job alone costs not far short of £7 an acre the value of these researches will be appreciated.

Weed Control

The farmer wages a constant war against weeds. For centuries weeds in rows of

growing crops were hoed by hand. Then came the horse-hoe to speed up the operation. But to-day hoeing is done with the tractor tool-bar, a simple arrangement of steel bars fitted to the tractor, and often attached to the hydraulic lift, to which are fixed the cultivating tools. With this tool-bar three and more rows at a time can be tilled with remarkable accuracy. Tool-bar hoeing competitions are now rivalling ploughing matches, for so long a feature of country life, so keen are farmers to get their men to become proficient in this department of their trade.

CROP SPRAYER

In quite recent years weed destruction has engaged the attention of chemists as well as engineers, and there is no doubt that these scientists have made spectacular progress. The "hormone" weed-killer and other chemicals are now used by contractors, who specialise in this work, and by farmers themselves, to an increasing extent, to combat weeds of various species in different crops.

Insect pests and fungus diseases in fruit, corn, vegetables and every other crop, are being kept in check by chemical fluids and dusts applied by machines, ever being improved and modified to give more effective service. The application of suitable chemicals from the air, by means of specially adapted aircraft, has passed the experimental stage and a service of that sort is actually at the command of farmers, at a price which is commensurate with the work done.

Electricity and Water Supplies

Ley farming has been mentioned—that is, the growing of better varieties of grasses and clovers. The successful management of a ley depends very often on planned and controlled grazing of the herbage by livestock. This cannot be done without fences, and fences are costly things to erect. Further, the management of a modern ley demands the moving of the fence at frequent intervals. This difficulty has been successfully overcome by the electric fence. Only a few years ago electric fences were regarded as something in the nature of freak appliances, but that is not the position now. An electric fence is very simple, needing a mere two, or at the most three, strands of wire, hung on to light and easily erected posts, a car battery and a small portable induction coil. Cattle, horses, sheep, pigs and even rabbits soon learn to respect the electrified wire and keep well away from it.

Electric power, of course, is of incalculable benefit to any agricultural holding, and the farmer soon starts to worry the supply authorities when electric mains come anywhere near him. Apart from lighting, electric motors are used to drive the stationary machines on a farm, such as milking machines. Some other uses to which electricity is readily put on the farm are for sterilisers and water heaters in the dairy, electric hot beds and soil sterilisers for the market gardener.

Adequate supplies of pure water are of paramount importance to milk-producing holdings, and to this end the Government has done a great deal to help dairy farmers to get all the water necessary for the production of that clean milk which forms such a vital part of the whole country's food supply. A special branch of the Ministry of Agriculture deals with water supply, and the work it has done is by no means the least of the factors which have contributed to the cessation of milk rationing.

This tale of the use of machinery to increase the productivity of the land could go on to great lengths. Actually, only some of the modern machinery can be mentioned, because the husbandman uses many and diverse tools in plying his craft. There is a constant demand that the tools should be improved, that new ones with greater output should be available, and that anything to bring down the costs of production and to increase what a man can do in a day must be made. Designers and manufacturers are ever seeking to supply what is wanted The great objective of attaining self-sufficiency is thus being vigorously pursued.

The Aviation Engine*

By Air Commodore F. R. BANKS, C.B., O.B.E., M.I.Mech.E.†

No. II—(*Continued from page 260, February 23rd*)

Future Developments

THE specific thrust of centrifugal turbo-jet engines now produced is between 315 lb. and 460 lb per square foot of frontal area, and that of an axial engine is about 700 lb per square foot. When a satisfactory annular type of combustion chamber has been developed it should be possible to build an axial engine of 10,000 lb thrust for an overall diameter of about 40in, or a thrust of 1150 lb per square foot.

The largest centrifugal type of turbo-jet so far built is the Rolls-Royce "Tay," of static thrust 6250 lb and diameter about 50in.

To boost the power of turbo-jet engines it is now usual to employ after-burning or reheat. This comprises a set of fuel burners placed in the jet pipe, some distance aft of the turbine. The burners are controlled by the pilot, to give additional power for take-off or for combat. After-burning, which can be likened to an assisted ram jet, makes use of the excess or unburnt air that has passed through the engine, to increase the total thrust. Naturally, burning fuel in this way is very expensive and the fuel consumption per pound of additional thrust rises considerably, which limits the period of after-burning to only a minute or two.

The increase in thrust by after-burning is about 25 to 30 per cent at sea level static conditions, an increase which is nearly doubled at high altitude and speed.

Fuel Economy.—At the present time (1950) the specific fuel consumption of turbo-jet engines in service is in excess of 1 lb per pound thrust per hour at static sea level conditions. This has, until recently, applied to both the centrifugal and axial types of engine, but there are axial engines now running which give a specific consumption below 0·9 lb thrust per hour, and it should be possible to reduce this to 0·85 lb within the next five years. The latter figure can be obtained with a compressor adiabatic efficiency of 85 per cent, a pressure ratio of 6·7/1, and a turbine efficiency of not less than 87 per cent.

Whereas the fuel consumption figures quoted are on the basis of full static thrust at sea level, at normal temperature, it is also necessary for the aircraft designer to know the engine performance at the operating altitude of the aircraft.

To achieve a specific fuel consumption of 0·8 lb per pound thrust per hour, and less, will probably necessitate a compounded engine; that is, one having two compressors in series on separate (coaxial) shafts, driven by separate turbines, to obtain the desired pressure ratio, which, in this case, will be between 8/1 and 10/1. The alternative is, of course, the ducted-fan engine, but whereas this type will give high thrust and improved propulsive efficiency at take-off and climb conditions, its best performance is limited to aircraft speeds of about 650 m.p.h.

Relighting at Altitude.—One of the difficulties experienced with current turbo jet engines is the relighting of a stopped engine at altitude. At present the effective relighting altitude varies from about 10,000ft to 20,000ft, according to the particular engine. However, experimental relighting has now been achieved at an altitude in excess of 40,000ft, and therefore it is not considered that the present difficulties are fundamental.

Another drawback, after getting a relight at altitude, is that of accelerating the engine to full speed from its starting speed, which is usually less than 2000 r.p.m. This is due to the difficulty in getting the flame to propagate from one combustion chamber to another.

The annular combustion chamber should

* James Clayton Lecture. Institution of Mechanical Engineers, February 16th. The lecture was divided into two parts. The first dealt with the piston engine and the second with the gas turbine. In the first part, the development of the piston engine was discussed with emphasis upon those factors, such as supercharging and improved fuel, which have particularly contributed to its present high performance. Cooling developments of both the air and the liquid-cooled engine were discussed, and also the influence of such detail refinements as the sodium-cooled valve and sparking plugs having sintered aluminium oxide insulators. We reprint only the second part of the lecture.

† Technical manager and chief engineer of the Associated Ethyl Company, Ltd.

reduce or eliminate the difficulties of altitude relighting and also ensure good flame propagation. The high pressure ratio compressor will also help in altitude restarting.

Engine Weight.—The question of engine weight is always important, and the specific weight of the turbo-jet should not exceed 0·35 lb per pound thrust. This might be reduced to 0·3 lb per pound thrust in about five years.

The specific weight is usually based on the "dry" weight of the engine and includes the accessories necessary for its functioning, but not those driven by the engine for the aircraft services.

An aviation engine must always be designed for low weight in the first place, and careful checks made during the design stages to ensure that the prototype engine will not exceed its designed weight. It is rarely possible appreciably to reduce the weight of a heavy engine after it has been built; but a light engine can be strengthened considerably without too much penalty in added weight. The practical way of dealing with weight in a heavy engine is to increase its power and therefore improve the power/weight ratio. This is not, however, always desirable in the gas turbine, since the engine will have been designed in the first place to fit a particular aircraft and the greater power may be embarrassing to fuel consumption and range, particularly if there are also Mach number limitations. Any extra engine power can then only be made available to improve take-off and climb, with the risk that the engine has to run at below its economical speed in level flight.

The Propeller Turbine.—The propeller turbine can be designed to give any desired proportion of propeller thrust relative to jet thrust, and the ratio between the two will vary according to the operating requirements of the aircraft. For instance, in the Allison T.40 unit, the combined output is, apparently, divided to give 5100 s.h.p. at the propeller, with 1600 lb of thrust at the engine exhaust or jet pipe.

For powers of 6000 e.h.p. (s.h.p. plus jet thrust) and higher, the duplex engine arrangement is preferable, consisting of two medium-size engines coupled through gearing to the same propeller, since the scantlings and stresses in the engine components can be kept to a reasonable figure. A single engine of higher unit power would probably have a high specific weight, due to the disproportionate increase in scantling size. The specific weight of a 6000 e.h.p. propeller turbine should not exceed 0·50 lb per e.h.p.

It is possible that within seven years a propeller turbine of this power may be built, to give a specific fuel consumption of about 0·55 lb per e.h.p. per hour. Such an engine would probably be of the compounded type, with two compressors in series on separate (coaxial) shafts, having an overall pressure ratio of 12/1.

Gas Turbine Fuel.—The supply of aviation fuel, both in regard to quality and quantity, is largely controlled by the strategic military position.

At present, British and United States military aircraft use kerosene, but all gas turbine engines intended for military use are also tested on aviation gasolene—usually 100–130 grade leaded fuel—in case they have to use it in an emergency and because there are still many piston-engined aircraft in the Services of both countries. The United States Navy fly their turbo-jet machines on aviation gasolene, because of the fuel problem in aircraft carriers and the difficulty of dual-fuel storage.

Since gasolene represents the major requirement from the barrel of crude oil, the supply of any other refined product of the crude oil will be controlled in a direct relation to the world demand for gasolene.

In the catastrophic event of another World War within, say, the next five years, the aviation gas turbine would be committed to a fuel having a predominance of hydrocarbons in the gasolene boiling range, to ensure adequate supplies. This would result in a loss of operating range of anything up to 10 per cent for a given aircraft tankage, since a gasolene type of fuel would reduce the total volumetric heat value. It might also cause operating difficulty and further loss due to its relatively high vapour pressure. It should, however, be quite possible, by a change in refinery processing, to produce a fuel of 1 lb to 2 lb Reid vapour pressure, suitable for military use and available in quantity within five years.

In regard to turbine fuel for civil aviation purposes, the gasolene type of fuel of high vapour pressure should be avoided at all costs. If, however, it is possible to produce a military fuel of not more than 2 lb Reid vapour pressure, this should also be acceptable for civil needs.

For the first time in the history of aviation an engine has been produced—the gas turbine—which does not need a fuel of high vapour pressure, and in the interests of safety in passenger carrying aircraft a fuel of low volatility is most desirable.

For the next five years there should be sufficient kerosene to meet the relatively small demands of turbine-engined civil aircraft; but one of the principal difficulties of the kerosene type of fuel is to ensure a sufficiently low freezing point, which must not be higher than —40 deg. Cent. This is particularly important when it is realised that most civil aircraft fitted with gas turbines will fly at considerable altitude, between 35,000ft and 40,000ft. Military aircraft will be required to operate at still greater altitudes, and will require fuel having a freezing point of 20deg. to 30 deg. lower than —40 deg. Cent.

Engine Maintenance.—Even during its relatively short existence the gas turbine has shown that it requires less day-to-day maintenance than the piston engine in normal aircraft operation, although it has not yet achieved the same total operating time between overhauls as the latter. But there is no fundamental reason why the gas turbine cannot eventually achieve the same running time as a well-developed piston engine, which, for the latter type in airline service, is now 1000 hours.

Present turbo-jets in military use, according to their state of development, are giving between 100 and 350 hours of service before removal for maintenance. Combustion chamber inspection is still necessary at intervals of fifty or a hundred hours, but further experience with this type of engine should render such intermediate inspections unnecessary.

Since performance is the criterion of the military engine, it is unnecessary for this type to go beyond 500 hours' operation between overhauls, but it should be completely reliable during this period. In peacetime, military aircraft are slow to accumulate flying hours and, for one reason or another, the airframe will eventually require maintenance before this time. Therefore there is no particular advantage in having a very long-lived engine, since it will probably be removed in any case when the aircraft is withdrawn for maintenance. It is then more easy to put in a new or serviced engine, so that engine and airframe maintenance do not get out of step. In wartime an engine is unlikely to see out its full running time and will probably only average 100 hours' flying before it is removed on account of battle damage.

Influence of Aviation Engines on Automobile Engines

Since aviation and automobile engines operate under different conditions, and have diverged considerably with time and experience, the contribution of the aviation engine to the improvement of the automobile engine has been mainly a matter of detail—but important detail. These contributions include improved coolant flow in the cylinder head, pressure cooling, better bearing technique with new bearing materials, the development of heat and corrosion-resistant valve steels and valve facing materials, sodium-filled valves and greatly improved sparking plugs.

The principal difference between the aviation engine and that of the automobile is that the former operates at constant speed and load, whereas the latter works at widely varying power and speed and, generally, at relatively low power.

The specific power output (brake horsepower per cubic inch) of the aviation engine at a cruising power equivalent to 50 per cent of the maximum or take-off power, is about the same as that of the average automobile engine at full power. Under these conditions the aviation engine in airline service is now expected to operate for 800 or 1000 hours before it is removed for overhaul. Assuming a block-to-block speed of 200 m.p.h., this represents a total mileage between overhaul periods of between 160,000 and 200,000 miles.

The automobile industry gave the liquid-cooled aviation engine the secondary surface radiator in place of the obsolete honeycomb type.

Design and Development.—The development of a successful aviation engine is a long and expensive undertaking, and occupies between four and five years from the first line on the drawing board before an entirely new engine is ready for production. The gas turbine demands more time spent in calculation, before and during the actual design stages, than is necessary for the piston engine, but there is generally less time on the test bed. Therefore the total time to make the gas turbine ready for production will be very similar to that needed for the piston engine, with a possible reduction, later, as the result of more experience. For the simple Whittle type of turbo-jet, with a centrifugal compressor, the development period of about four and a half years can be nearly halved.

The gas turbine has brought a change in the design and engineering departments. In addition to the staff needed for proper mechanical design and testing, there must now be included some high-level mathematicians and aerodynamicists.

While such lengthy and expensive development is not required for a new automobile or vehicle engine, many manufacturers could with benefit enlarge their engineering departments—some of which exist only in name and consist of a small design office of limited capacity, largely subordinated to the whims of management and sales.

An engineering department will not only include facilities for engine study, but also those for investigating chassis problems, &c. This is a particularly important consideration, since the life or obsolescence of the average automobile is between ten and fifteen years, and it is most necessary to ensure that every advantage is taken of any technical advance to improve the type in detail and also to ensure that the design office has all the information possible to enable the

designers to make the best of a new design.

For instance, an engine designed to-day should have inherent in it the possibility of raising the compression ratio, without a major change or distortion of the combustion chamber shape, when better fuel becomes available. Also included in the basic design will be increased scantlings of the main cylinder block and crankcase structure, to accommodate a stiffer crankshaft and ensure a smooth engine, free from vibration when running with high compression ratio.

Conclusion

The first half-century of aviation is now practically completed and, as the gas turbine becomes established, the second half of aviation's century may bring big changes in the world by the increasing rate of air transport, further to reduce space in terms of time.

The piston engine, which has served aviation well, should continue to do so for about another ten years, but will by that time have assumed second place. Its future will then be controlled by the obsolescence of the aircraft in which it is fitted and also by the gas turbine's suitability or otherwise for such machines as feeder line and executive aircraft, where first cost and operating flexibility are of chief importance.

In Appendix I are some comments on the application of the gas turbine to road vehicles.

It has not been possible to give a full discussion of aviation engine development in all its aspects, and those wishing for more detail are referred to an excellent treatise on the subject by Schlaifer and Heron (1950).

Acknowledgments.—The author wishes to acknowledge help received from Messrs. Armstrong Siddeley, The Bristol Aeroplane Company, D. Napier and Son, Rolls-Royce, and Vickers-Armstrongs. He also tenders his grateful thanks to Mr. Pitchford for his helpful criticism and good advice.

The author thanks his firm, The Associated Ethyl Company, Ltd., for permission to present this lecture.

APPENDIX I

The Gas Turbine for Road Vehicles

The gas turbine is not an impossibility for the automobile; experimental engines are being designed and some are already under test, but the turbine does not appear to have advantages compared with the normal piston engine, for this purpose. It may well have useful application in certain large commercial and military vehicle types and, perhaps, for the long-distance passenger coach.

In the first place, the most suitable size of gas turbine to give reasonable efficiency is better fitted to the needs of the large vehicle rather than the automobile, since it is more easy to build an efficient gas turbine of 250 s.h.p. than one of 50 s.h.p. or 100 s.h.p. Scaling the engine down to these comparatively low powers demands lengthy and expensive development, to obtain the required efficiency of components such as the compressor, the combustion chamber and the turbine.

Smoothness of operation and lack of vibration, inherent in the gas turbine, are now so good in the piston engine that a change to the former on these grounds alone can hardly be justified.

The idea that the gas turbine will use "any old fuel" may not be confirmed in practice in the relatively low-power vehicle engine. While anti-knock or detonation value is unimportant, the fuel must be fluid at all temperatures likely to be encountered in cold climates; and it must also give clean combustion, so that frequent cleaning or decarbonising of the combustion chamber is not required. This would seem to rule out the so-called boiler or heavy fuels, because of their relatively high freezing point and their ash and asphaltic contents, &c. Light diesel or gas oil, or kerosene, are therefore likely to be used, but they may be in short supply if any large number of turbine-engined vehicles emerge on the highways.

To compete with the piston type of petrol engine the thermal efficiency of the gas turbine cannot be much less than 25 per cent. Although the efficiency of the former is relatively low at part-throttle and, with the constant accelerations and decelerations of the automobile in ordinary usage, that of the gas turbine is likely to be considerably less. The gas turbine is a constant-speed or "full-throttle" engine and therefore its efficiency falls off seriously at engine speeds much below the maximum. The provision of a heat exchanger may, however, help in this respect.

The gas turbine will also have to meet the competition of the very high-compression piston engine, the development of which has now been brought to a practical stage (General Motors Research of America (Kettering 1947; Campbell, Caris and Withrow 1948)).

An advantage of the gas turbine for automobile propulsion is that it should be possible to dispense with the multi-speed gearbox, since the usual arrangement of a free turbine separated mechanically from the turbine-compressor system of the engine, will provide its own very satisfactory torque converter. A low-speed gear, for very steep gradients, and a reverse gear will probably be the only mechanical speed changes required. But a multi-speed box may still be necessary for the heavy road vehicle.

The vehicle gas turbine will have a centrifugal compressor, since the axial type is somewhat impracticable and expensive to produce. Therefore the pressure ratio of a small two-stage centrifugal compressor is hardly likely to be much more than 5/1 and it will do well to give 74 per cent adiabatic efficiency. The matter of turbine efficiency is the most important for fuel economy, since 1 per cent improvement in turbine efficiency will be equivalent to about 3 per cent improvement in fuel consumption. Since the efficiency of the aviation turbine is about 87 per cent, a similar efficiency will be difficult to achieve with such a comparatively small turbine. In view of the low pressure ratio of the compressor and the probable limitations in component efficiencies, a heat exchanger will be required.

Since the gas turbine will pump anything between six and ten times more air than the piston engine, for equal power output, the problems of silencing the air intake and exhaust disposal are not inconsiderable, although perhaps not insuperable.

If the gas turbine eventually challenges the piston engine in the automobile, as distinct from its use in the heavy vehicle, this may come about purely as the result of an urge to be different, and not because it shows any better economy than the piston engine. Peculiar as it may seem, engineers often follow fashion for fashion's sake; but it is to be hoped that any such change to the turbine will be made only on the grounds of sheer merit, before discarding the many decades of experience of the piston engine.

Finally, if the gas turbine were to be used in the automobile, it would have to be dealt with as a "packaged power unit," because the average garage or motor engineering concern would be unable, for some time, to handle any of the major or even minor maintenance problems of this type of engine. This would involve a considerable extension of the supplier's manufacturing and servicing facilities, to ensure a cushion of power units to meet such contingencies.

The Aerodynamic Wind Tunnel at Modane-Avrieux

By Dipl.-Ing. C. CARTY

WHEN the Allied forces entered Austria in 1945 the French troops found in the area of occupation assigned to them the components in course of erection of a large aerodynamic single-return wind tunnel for the large-scale testing of aircraft engines and models. In order that this material might, after its seizure as war booty, be used in France for research purposes, it was in the first place essential to locate a source of water power suited to the original working conditions.

Following a close examination of the available possibilities it was decided to re-erect the material available adjacent to an electric power station in course of construction on the left bank of the River Arc, within the grounds of the village of Avrieux, about 2½ miles upstream from Modane, the French frontier station, just short of the Mont Cenis Tunnel (Fig. 1).

The Wind Tunnel

The wind tunnel is rectangular in shape, as will be seen from the diagrammatic lay-out (Fig. 2), which shows the general arrangement and the main dimensions. The diameter of the jet at the test section (*B*) amounts to 26ft 3in (8m) and rises gradually, starting from the right up to a diameter of 78ft 9in (24m) ahead of the entrance cone (*A*) on the left of the test section. The actual area covered by the wind tunnel is 574ft ¾in by 210ft (175m by 64m). The wind tunnel plates, which vary in thickness between $^{5}/_{16}$in and $^{15}/_{32}$in (8mm and 12mm), have been assembled by electric welding.

About every 52ft 8in the wind tunnel is carried on deflection-resisting supporting rings. These rings are suspended on the one hand from the exterior pendulum stanchions visible on Fig. 4, and are held in addition at the bottom by pivot pins. These pivot pins had to be provided because otherwise the difference in temperature between the wind tunnel side exposed to the sun and that remaining in the shadow on account of the East-West alignment of the valley of the Arc, might have resulted in excessive stresses liable to distort the setting out of the plates.

Hollow vanes with adjustable shutters have been provided at the four corners (*F*) of the wind tunnel, each of which acts as a fixed point, together with those adjoining the test section and the propeller blowers. Expansion joints are fitted between these fixed points throughout the circuit.

The air necessary for the operation of the wind tunnel is impelled by two propeller blowers (*E*) of 49ft 3in (15m) diameter each, the pitch of which can be varied when at rest. In order to avoid any synchronous vibrations, one of the propellers is provided with ten and the other with twelve blades, made from steel plates mounted on the 23ft (7m) diameter forged steel bosses, while they rotate

in opposite directions at a maximum speed of 250 r.p.m.

Motive Power

In addition to the material used for the actual wind tunnel, there were seized some components of two Pelton turbines, supplied by Messrs. J. M. Voith, of Heidenheim, and St. Pölten (Austria). The runner wheels of these turbines were the deciding factor when selecting the French location of the wind tunnel, as it was necessary to make arrangements to feed them from a branch of the water supply to a hydro-electric power plant of the Electricité de France presenting characteristics of head and flow appropriate to their further use.

These requirements were met by the characteristics of the Aussois power station in course of erection on the left bank of the River Arc, at a short distance from the village of Avrieux. It proved possible to use one of the two turbine wheels directly after overhaul, but the other required completion and was sent to the Grenoble works of Messrs. Neyret and Bélier. Each of the two turbines is located within a separate building (*J*) on either side of the right-hand small end of the wind tunnel area, and is connected with the propeller blower by line shafting 105ft (32m) long. Each turbine has an output of 54,247 h.p. at 250 r.p.m., under an overall head of 2855ft (870m), corresponding to an actual head of 2690ft (820m). The Pelton turbine wheels are about 14ft in diameter (4·24m) and are provided with two variable flow main valves, together with an auxiliary valve, maintaining a constant speed under light load variations. A counterflow pipe is also provided for braking purposes in order to cut short the time required for stopping the plant. The governors maintain the speed of the two turbines constant within ±0·05 of the rated speed.

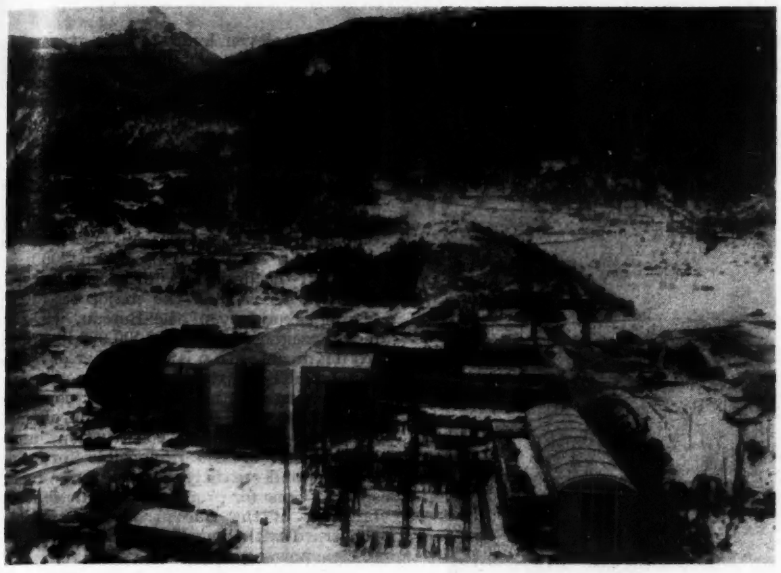


Fig. 1—Wind Tunnel at Modane-Avrieux

Air Intake and Cooling Systems

The main air inlet is provided by two vertical tubes, shown at *G* on Fig. 2, and illustrated in Fig. 3, the tubes being fitted with adjustable leakage rims. The air is admitted at the top and bottom of the tubes and is subjected to a deflection through 90 deg. in order to escape horizontally and parallel to the flow of the vine. By suitably adjusting the leakage rims it is possible to arrange for the volume of fresh air admitted to amount to 25 per cent of the total flow of the wind tunnel. When motor tests are in progres it is, moreover, possible to admit up to 50 per cent of the total air volume required, by means of the annular ring inlet ahead of corner *F* at *D* in Fig. 2. The warm air escapes to atmosphere through the ring space of the air exchanger and settling chamber (*K*), which is immediately ahead of the entrance cone and has an area of about 1075 square feet (100 square metres). This arrangement offers the additional advantage of preventing the low-speed boundary layer of the jet from entering the test section.

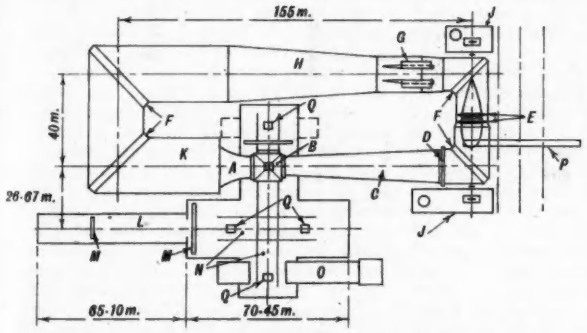


Fig. 2—Diagrammatic Arrangement of Wind Tunnel

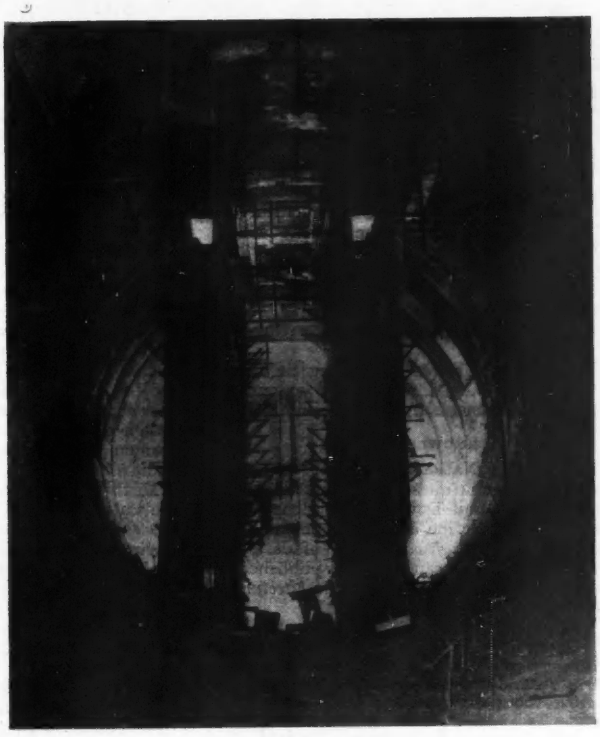


Fig. 3—Inlet Tubes

Testing Carriage

As the time required for the assembly and weight recording of the different components being tested is far more extensive than that required for the actual tests themselves, which take place during the periods the electricity generating station is shut down for production, four testing carriages (two for aerodynamic and two for motor tests) have been provided. The components for testing may therefore be assembled, weighed or tested quite independently of each other. Each of these mobile testing carriages is provided with a testing and with a pressure chamber. Three testing carriages are at present in the course of assembly.

The testing chamber (*B*) enclosing the length of jet used for recording purposes is a tube 46ft (14m) in length and of circular cross-section, having a diameter of about 25ft 6in (7·78m) on the cone or entry side (*A*) and of 26ft 3in (8m) on the diffuser side (*C*) in Fig. 2, the pipe being rigidly connected at both ends. A depression chamber is beneath the testing jet, with which it is in direct communication.

Buildings

Alongside the wind tunnel is a building cross shaped in plan, the two bays of which are 230ft and 262ft 6in in length (70m and 80m), while their heights are 82ft and 98ft 6in (25m and 30m) in order to allow for the free passage of the two 10-ton overhead cranes, which travel across them. These bays contain the testing carriage (*Q*) with components in the course of assembly or being weighed. As these testing carriages move on tracks (*N*) at right angles to each other, hydraulic jacks are used to rotate the carriage bogies at the rail crossing.

The test bed (*O*) for the mechanical fitting of engines to be tested is provided with two vertical chimneys of 689 square feet (64 square metres) cross-section for drawing in fresh air and exhausting the burnt gases. It is hoped that the arrangement and equipment of these chimneys will lessen the noise to a certain extent.

The frames as well as the roofs and vaults of these buildings are in reinforced concrete. In some places the nature of the subsoil called for large-scale piling foundation work. The size of the different building works to be

carried out is evidenced by the following quantities :—

Excavation	261,600 cubic yards
Mass and heavy concrete ...	22,235 cubic yards
Reinforced concrete	5,395 cubic yards
Concrete reinforcement	1,240 tons
Shuttering	323,000 square feet
Wind tunnel steelwork	5,413 tons

Operation

The air is drawn into the wind tunnel by the difference between the up and downstream pressures caused by the two propeller blowers, a difference which may attain up to 1640ft (500m) of water.

The air speed should vary between 213ft and 985ft per second, depending on the blade pitch selected, the corresponding energy consumption varying between 8088 h.p. and 108,500 h.p. For the maximum speed the depression in the jet will attain about 7 lb per square inch, which corresponds to the atmospheric pressure at an altitude of 18,045ft, the height of the wind tunnel itself being about 3940ft above sea level. For an outside temperature of +15 deg. Cent., the jet temperature will be +5 deg. Cent.

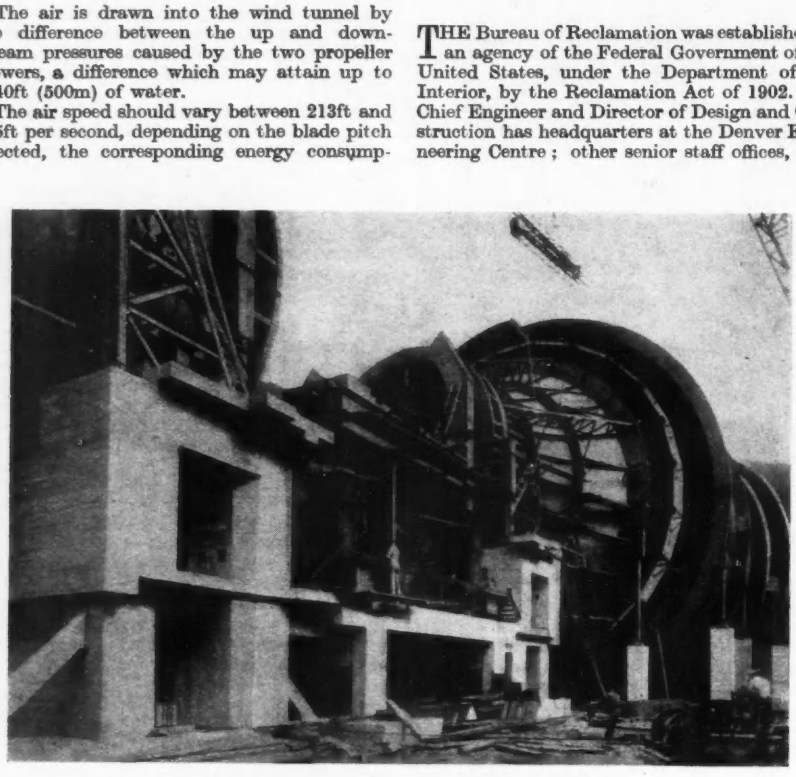


FIG. 4—TESTING CARRIAGE AT WORKING SECTION

This wind tunnel will facilitate the carrying out of tests of a varied character over a very wide range, not only of wing sections but also of jet engines, exerting a thrust of up to 10 tons.

Finally, a speciel testing carriage is at present being developed, which will extend the range of possible tests up to supersonic speeds.

Acknowledgments

The "Office National d'Etudes et de Recherches Aéronautiques" (National Aeronautical Research and Development Board) is in charge of the erection and development of the wind tunnel. A limited amount of data have been taken from an article published in the October, 1949, issue of *L'Architecture D'Aujourd'hui*.

REPORT ON THE CANADIAN INTERNATIONAL TRADE FAIR, 1950.—A report has been published covering the participation of the British Tool, Machine Tool and Scientific Instrument Section in the 1950 Canadian International Trade Fair at Toronto. This report deals with all aspects of the preliminary work undertaken, describes the problems that arose and were solved before and during the course of the Fair, and presents a careful analysis of requisite following-up action based on the experience gained in Canada. It deals with the correct approach to the Canadian market, and publicity and includes the special reports of the seven British Associations, which comprised the section. The British Machine Tool Section will again be strongly represented in the 1951 Fair, to be held in Toronto from May 28th to June 8th.

The United States Bureau of Reclamation

THE Bureau of Reclamation was established as an agency of the Federal Government of the United States, under the Department of the Interior, by the Reclamation Act of 1902. Its Chief Engineer and Director of Design and Construction has headquarters at the Denver Engineering Centre; other senior staff offices, concerned with project planning, power utilisation and operation and maintenance, have offices in the Interior Building at Washington, D.C.

The Bureau of Reclamation is devoted to the task of conserving and developing irrigation, hydro-electric power and related water resources of the seventeen Western States of the U.S., and putting them to beneficial use by the construction of engineering works. Since 1902 the Bureau of Reclamation has constructed 160 dams and 96 reservoirs, 20,000 miles of canals 200,000 irrigation structures, 107 miles of tunnels, and 33 power plants, to list only the major items. Grand Coulee, Hoover and Shasta dams and the Missouri River basin project all come under the auspices of the Bureau, which has also co-operated in the design of such structures as the Ichang Gorge dam on the Yangtze River and the Kosi dam in India.

Much still remains to be done in developing the water resources of the Western States. In the early days small projects were developed, having limited and local scope. Over the years projects increased in magnitude as demands for more water and power accompanied the growth of the West. But it has become evident that piecemeal development of individual projects, no matter what their magnitude, will not put all the water of the West to the most beneficial use. The present reclamation programme contemplates the unified development of entire river basins so that all the engineering works constructed on a main stream and its tributaries will be co-ordinated and complementary, so that individual projects may contribute to the maximum development of the basin as a whole.

Of the Bureau's 400,000,000 dollar budget for the fiscal year, 368,237,255 dollars were allocated to construction, 17,668,754 dollars to operation and maintenance, and 8,063,000 dollars to investigation and advance planning. The present programme, involving seventy-five construction projects, includes work on thirty-two dams, eleven hydro-electric power plants, about 4000 miles of power transmission lines, and several hundred miles of canals and leats for the distribution of irrigation waters. The table on page 283 shows the installed capacities of the Bureau's hydro-electric power projects, but it should be remembered that these developments also involve the irrigation of large areas.

The new Engineering Centre at Denver, Colorado, which occupies an area of 20 acres and has a staff of more than 2000, is the technical headquarters of design and construction as well as the major research and testing laboratory of the Bureau, with equipment ranging from a 5,000,000 lb universal testing machine to a large number of hydraulic scale models of reclamation structures. The Engineering Centre guides and controls the engineering work of the Bureau in all matters involving design and construction, and the organisation is also responsible for administrative and managerial matters, including specifications for proposed construction. Other branches of the Bureau of Reclamation are concerned with hydrology, water supply and electric power generation.

Categories of engineering not requiring the special facilities of the Centre may be delegated to engineers and other technologists under the Bureau's seven regions, covering the seventeen Western States. Responsibilities of the Engineering Centre in connection with the latter category normally include the establishment of basic criteria and methods, definition of standards of accuracy and quality, surveillance of work in progress and review of work completed.

The physical features of a reclamation project are usually such that the Bureau of Reclamation must make its own designs. For this reason a large portion of the Reclamation Engineering Centre in Denver is devoted to design and related activities. For administrative purposes the designers are grouped into seven major divisions, which are primarily concerned with the design of dams, canals, electrical work, mechanical work, structural and architectural work, hydraulic machinery, and drainage. These design divisions have assistance from other divisions, such as groups specialising in research and geology and administrative engineering.

During nearly fifty years of experience in the design and construction of reclamation structures, the Bureau of Reclamation has accumulated a large store of recorded information showing the manner in which the designs of past years have acted in service. This recorded information is stored in files and on microfilm at the Reclamation Engineering Centre, so that it is readily available to the designers to guide and to serve as a check. As reclamation projects have progressed from the simple irrigation projects to the more complex multi-purpose projects, the size of structures has gradually increased and methods of design have, themselves, undergone corresponding changes. Design methods used at the Centre have attained increased efficiency in recent years with the introduction of standard practices wherever possible. Standard analyses of "type" structures are made in order that succeeding analyses of "specific" structures may be made in a minimum of time. Design productivity per man has thus been increased substantially in recent years, as shown by the successful handling of a rapidly increasing annual reclamation programme with only a slight increase in staff. While field operations are under the immediate supervision of construction engineers at the site, construction as a whole always remains the responsibility of the Chief Engineer and his staff at the Engineering Centre at Denver.

Summary of Bureau of Reclamation Hydro-Electric Power Developments

State	Project	Name of plant	First year of operation	Existing installed capacity (megawatts)	Ultimate installed capacity (megawatts)
Constructed and Operated by Bureau of Reclamation					
Arizona-Nevada	Boulder Canyon	Hoover	1936	1034·8	1332·3
Arizona-California	Parker	Parker	1942	120	120
California	Central Valley	Shasta	1944	379	379
Ditto	Ditto	Keswick	1950	75	75
Ditto	Yuma	Siphon Drop	1926	1·6	1·6
Colorado	Colorado-Big Thompson	Green Mountain	1943	21·6	21·6
Idaho	Boise	Boise Diversion	1912	1·5	1·5
Ditto	Ditto	Black Canyon	1925	8	8
Ditto	Minidoka	Minidoka	1909	13·4	13·4
Wyoming	North Platte	Guernsey	1927	4·8	4·8
Ditto	Ditto	Lingle	1919	1·4	1·4
New Mexico	Rio Grande	Elephant Butte	1940	24·3	24·3
Washington	Columbia	Grand Coulee	1941	1424	1974
Ditto	Yakima	Prosser	1932	2·4	2·4
Wyoming	Kendrick	Seminoe	1939	32·4	32·4
Ditto	Missouri Basin	Kortes	1950	12	36
Ditto	Riverton	Pilot Butte	1925	1·6	1·6
Ditto	Shoshone	Heart Mountain	1948	5	5
Ditto	Ditto	Shoshone	1922	5·6	5·6
				3168·4	4037·5
Constructed by Bureau of Reclamation, Operated by Others					
Arizona	Salt River	Roosevelt	1909	15·4	15·4
Ditto	Ditto	Arizona Falls	1913	0·85	0·85
Ditto	Ditto	Cross Cut	1914	5·1	5·1
Ditto	Ditto	S. Consolidated	1912	1·6	1·6
Colorado	Grand Valley	Grand Valley (Palisades)	1932	3	3
Nevada	Newlands	Lahontan	1911	1·78	1·92
Oregon	Deschutes	Cove	1946	1·5	1·5
Utah	Strawberry Valley	Spanish Fork	1908	1·55	1·55
Washington	Yakima	Rocky Ford	1916	0·187	0·187
				30·967	31·107
Constructed and Operated by Water Users' Organisations					
Arizona	Salt Rivef	Chandler	1919	0·6	0·6
Ditto	Ditto	Horse Mesa	1927	30	30
Ditto	Ditto	Mormon Flat	1926	7	7
Ditto	Ditto	Stewart Mountain	1930	10·4	10·4
California	All-American	Drop No. 3	1941	4·8	9·6
Ditto	Ditto	Drop No. 4	1941	9·6	19·2
Oregon	Klamath	"C" Canal Drop	1938	0·5	0·5
				62·9	77·3
Constructed and Operated by Corps of Engineers, Department of the Army					
Montana	Fort Peck	Fort Peck	1943	50	105
				50	105
Under Construction by Bureau of Reclamation					
Arizona-Nevada	Davis	Davis	1951	—	225
Colorado	Colorado-Big Thompson	Estes	1950	—	45
Ditto	Ditto	Mary's Lake	1950	—	8·1
Idaho	Boise	Anderson Ranch	1950	—	40·5
Ditto	Palisades	Palisades	1956	—	112·5
Montana	Missouri Basin	Canyon Ferry	1953	—	50
Ditto	Hungry Horse	Hungry Horse	1952	—	285
Wyoming	Missouri Basin	Boysen	1952	—	15
					781·1
Under Construction by Corps of Engineers					
North Dakota	Missouri Basin	Garrison	1955	—	400
South Dakota	Ditto	Fort Randall	1954	—	320
					720
Authorised to be Constructed by Bureau of Reclamation					
California	Central Valley	Folsom and Folsom Afterbay	1954	—	160
Ditto	Ditto	Nimbus	1953	—	5
Colorado	Colorado-Big Thompson	Polehill	1953	—	32·8
Ditto	Ditto	Flatiron	1953	—	63
Ditto	Ditto	Big Thompson	—	—	6·7
Montana	Missouri Basin	Angostura	1951	—	1·2
Ditto	Ditto	Lower Marias (Kenil)	—	—	1·6
Ditto	Ditto	Lyon	1959	—	24
Ditto	Ditto	Mission	—	—	50
Ditto	Ditto	Portage	1958	—	20
Ditto	Ditto	Yellowtail	1956	—	200
Nebraska	Ditto	Harlan	—	—	1·2
North Dakota	Ditto	Crosby	1957	—	48
Ditto	Ditto	Des Lacs	1957	—	60
South Dakota	Ditto	Miller Drop	1960	—	180
Washington	Yakima-Roza Div.	Roza	1953	—	10
Ditto	Yakima-Kennewick Div.	Chandler	1953	—	12
Wyoming	Missouri Basin	Bald Ridge	1959	—	30
Ditto	Ditto	Hunter Mountain	1960	—	12
Ditto	Ditto	Sunlight	1956	—	20
Ditto	Ditto	Thief Creek	1956	—	60
Ditto	Ditto	Tongue River	—	—	25
					1022·5
Authorised to be Constructed by Corps of Engineers					
South Dakota	Missouri Basin	Big Bend	1960	—	120
Ditto	Ditto	Gavins Point	1955	—	100
Ditto	Ditto	Oahe	1960	—	425
					645
Total				3312·27	7419·51

Turbine Problems in the Development of the Whittle Engine

THE Fifth Hatfield Memorial Lecture, dealing with turbine problems of the Whittle engine, was delivered to the Iron and Steel Institute by Air Commodore Sir Frank Whittle, K.B.E., C.B., M.A., D.Sc., F.R.S., in London, on Tuesday, February 20th. Sir Andrew McCance, LL.D., D.Sc., F.R.S., past-president, was in the chair.

In introducing his subject Sir Frank recalled that the broad history of the development of the gas turbine had been covered in his James Clayton Lecture of 1945, to the Institution of Mechanical Engineers, but that in attempting to focus attention more directly upon the particular problems of the turbine it would be desirable to restate some of the general history.

Sir Frank then referred to correspondence between himself and the late Dr. Hatfield, whose researches in the field of high temperature materials had made available, during the pioneering phase of 1935 to 1941, the requisite metals needed to prove that the scheme would work. With reference to the early designs, he recalled his first patent of 1930, which specified a compressor consisting of a single-stage centrifugal impeller, preceded by two axial compression stages, and he continued that in view of the present argument about axial versus centrifugal compressors it would be appreciated that he was "sitting very nicely on the fence."

Turning to the more particular turbine problems, Sir Frank explained that because of the interdependence of the compressor, combustion and turbine components, it was often difficult in the early days to determine the particular cause when things went wrong. There were times, he continued, when a defect in the turbine caused the compressor to surge and other times when bad combustion could not be distinguished from poor turbine efficiency. In the particular case of the first experimental engine, Sir Frank stated that it was never known how the turbine was doing as the compressor and combustion were never running well enough to find out.

The failure of the experimental engine in February, 1941, was finally brought about after four years work by the failure of the blade roots, which caused extensive damage. This engine, however, had served during this period to solve almost all the major development problems. It was at that time that the Air Ministry ordered a flight engine, along with an experimental aircraft. This engine, named the "W.1," was similar to the experimental engine but used sheet metal only $^1/_{64}$in thick in the combustion chambers, with magnesium castings instead of aluminium in the blower casings. The water-cooling jackets for the turbine disc were retained. The turbine was fitted with seventy-two instead of the earlier sixty-six blades, an increase which greatly improved the turbine efficiency.

In a later version the "W.1A," little vane blades were incorporated in the turbine wheel to effect a degree of air cooling and enable the water jackets to be dispensed with. Sir Frank went on to explain, however, that cooling air from the air-cooling vanes on the rear side of the rotor had led to the formation of a thick boundary layer in the exhaust, virtually choking the exhaust and causing the whole engine to surge. He also said of this engine that the exhaust velocity was 1250ft per second, which was getting near the velocity of sound for the temperature, so that the exhaust cross section was quite critical. Sir Frank stated that, intuitively, it was then decided to remove the air cooling blades on the rear side of the turbine wheel, which, he observed, at that time was an odd thing to do to stop the compressor surging, but it cured the problem.

The "W.2" engine was a later version, which was not successful mainly because the designed exhaust velocity of 1450ft per second was much too near the speed of sound. The "W.2B," which followed, had basically the same arrangement as the others and, finally

gave its designed thrust of 1600 lb and went into production as the Rolls-Royce "Welland."

There were several further variants of the "W.2" engine, in which the thrust was gradually increased and the last of these, the "W.2/700," eventually gave 2500 lb thrust. The size of all these engines remained much the same throughout this period.

In giving his account of experience with blade fixing, he spoke of considerable opposition to the fir-tree method of fixation, which he had advocated for the first engine. He was told, however, that manufacturing difficulties and some unsatisfactory previous experience with fir-tree fixing militated against its further use and consequently the first engine used the De Laval fixing method. In that turbine severe stress concentrations due to the fixing method finally led to its failure. The lesson learnt showed that, with disc cooling, a temperature gradient at the rim, estimated at something like 300 deg. Cent. per inch led to stresses, causing crushing between the blade roots if no relief was afforded by radial slots. The Americans, who had tried welding the blades into the wheels, also discovered this fact later, as radial cracks developed at the rim. The De Laval method of root fixing was soon abandoned and, using the fir-tree method, an allowance for rim expansion of 0·003in per blade-root was adopted. The fir-tree method was also the only type of blade-root fixing which enabled the requisite number of blades to be used without giving excessive stresses. Failures, which still continued at first with the "W.1A" blade roots, were found to be caused by too sharp radii and scratches in the broaching tool, by which both the blade-roots and the slots were machined. In discussing the stressing of blade-roots, he mentioned that a good deal depended on the plasticity of the material and that, if a material were used which did not yield plastically enough the load was not properly shared by all the teeth and cracks inevitably developed.

He recalled one particular series of blade failures occurring in 1941, when the "W.2B" engine was going into production, which was puzzling because of the inconsistent nature of the failure. It was finally thought that that series of failures was due to the insertion of a thermal couple at various positions in the exhaust pipe, causing a considerable pressure field ahead of the thermal couple, which might have caused momentary blade stalling on passing this field; the nature of the blade failure would then have been affected by the position occupied by the thermal couple. On removal of the thermal couple the particular incidence of blade failure dropped considerably.

He indicated that what really happened in blade design was that the passage between the blades was fixed and the blade-shape followed as a consequence. That was fortuitous in that it provided a change of section from root to tip, which allowed a good stress distribution.

The nozzle-ring in the earlier engines was made segmental but later the outer banding of the nozzle-ring was made in one piece with the shrouding of the turbine wheel and allowance was made for radial expansion of the blades. After some further references to tip clearance and to expansion problems during transitionary periods, a film, made by the Crown Film Unit, entitled "Wonder Jet," was shown.

The School of Gas Turbine Technology

THE study and development of the gas turbine have entailed intensive research into many aspects of mechanical engineering. Although in conception its roots truly belong to an earlier century, the barest knowledge of gas turbine technology suffices to explain why only academic interest had hitherto been shown in this project until recent years. With the impetus of war the spectacular success which then attended the development of Sir Frank Whittles' first patent of 1930 has now virtually established this form of propulsion for most types of aircraft. No other prime mover system, however, is also suitable alike for locomotives, ships, power stations and for the conversion into useful work of heat which might otherwise be lost in various industrial processes. Neither does any other power plant promise to digest as efficiently so great a variety of fuels. For most of these different purposes there are already numerous plants under development with others already in operation. There still remain, nevertheless, many problems, formidable enough to delay for some time a full realisation of the ultimate advantages inherent in the gas turbine; or even, for that matter, yet to attain the efficiencies which conventional plant are now able to give because of the many more years of development behind them.

An appreciation of the problems involved, of the work that has already been accomplished and the tremendous programme of research which is now going on, can be most properly appreciated at the School of Gas Turbine Technology. Probably the first of its kind in the world, the School was founded in 1944 to instruct Dominions' air force personnel in the application of the gas turbine to aircraft propulsion. It was then based at Lutterworth and operated by the National Gas Turbine Establishment, but since 1948 it has been directed by Power Jets (Research and Development), Ltd., a company normally constituted, but with the shares held by the Government. Power Jets are responsible also for the protection, all over the world, of nearly 3000 British gas turbine patents and inventions, and they act also as technical consultants to the industry. Since 1945 the school has rapidly extended its curriculum to embrace the many industrial aspects of this prime mover, and it now seeks to teach gas turbine technology in all its aspects as well as to encourage the technical instruction essential to the adequate staffing of the gas turbine industry, so rapidly growing at home and abroad.

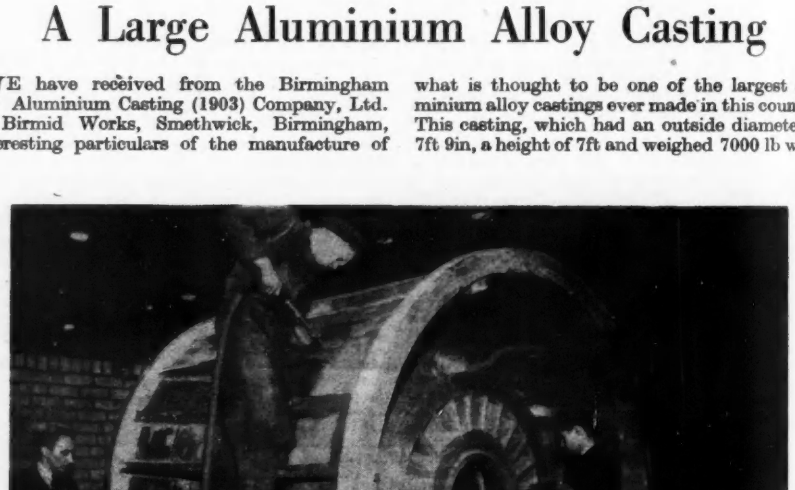
One of the main courses deals with the industrial gas turbine, which lasts three weeks and is of a post-graduate nature. As with the other three courses provided, pupils are normally resident at the school, which has recently moved and occupies the old manor house at Farnborough. The course considers at length the theory and design of centrifugal compressors and of axial compressors using both free vortex and constant reaction blading, the theory of turbines and the application of dimensional analysis to heat transfer with the design of heat exchangers. Other aspects of the theoretical work are concerned with the stressing of blading, discs and impellers, followed by general considerations of the effects and the avoidance in the design of vibratory stresses. Having established much of the theory, a great portion of the course is then devoted to the choice of cycle and the arrangement of the components to suit the many applications for the gas turbine towerds the development and establishment of which the staff themselves are actively engaged.

Particular attention is given to combustion problems in both open and closed cycles, with emphasis upon the development of coal-fired systems and upon methods of controlling the combustion, particularly when using either peat or pulverised fuel. There are many other lectures given by outside specialists engaged upon the various prototype gas turbine plants now under construction. Included also are examples of full load and part-load performance estimations, concluding with actual part-load tests on a Whittle engine and a "Naiad" shaft power engine.

The Principal of the School is Mr. D. L. Brown, A.M.I.C.E., M.I.Mech.E., M.Inst.Gas E., A.F.R.Ae.S., and there are five lecturers, who between courses are engaged upon consultant work. Most of the lecturers have been concerned with the gas turbine since the early experimental days at Lutterworth and each has a fund of stories telling of their early triumphs, disappointments, failures and even disasters. Pupils who themselves are mainly drawn from design offices and Government establishments, cannot fail, after this intensive study of the advantages, disadvantages, and the prospects of this prime mover, to be enthused with the optimism which permeates the School of Gas Turbine Technology.

A Large Aluminium Alloy Casting

WE have received from the Birmingham Aluminium Casting (1903) Company, Ltd. of Birmid Works, Smethwick, Birmingham, interesting particulars of the manufacture of what is thought to be one of the largest aluminium alloy castings ever made in this country. This casting, which had an outside diameter of 7ft 9in, a height of 7ft and weighed 7000 lb when



CASTING BEING FETTLED

despatched, was required for a rotary vacuum filter and was made to the order of International Combustion, Ltd., of Derby. Aluminium alloy was used because its anticipated life was greater than that of cast iron. A photograph of the casting in the maker's fettling shop is reproduced on the opposite page.

The pattern used for the casting was fully segmented and complete in itself, no strickles being used. It was made in twelve sections which were subsequently bolted into four units to facilitate transport to the foundry. Independent core boxes were also made for the internal and external body cores; this was necessary for the carrying of the grids essential in handling the heavy cores.

In the interests of accuracy, a four-part moulding box was used and, in order to facilitate pouring and as a safety measure (the value of the metal alone being well over £700), the job was rammed up in a moulding pit of suitable depth, so that when assembled for pouring the runner bushes were a convenient height above floor level.

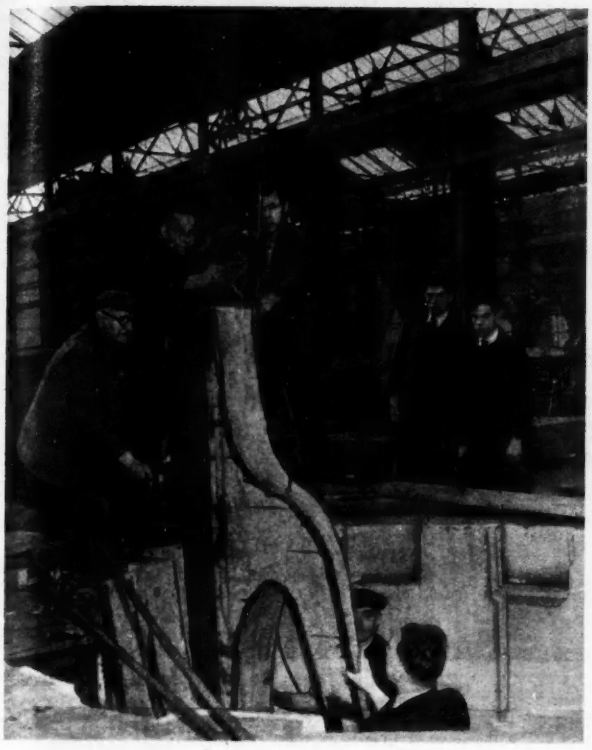
The first moulding box was bedded in and four steel channels were used to provide a base for the secure fastening of the internal body cores. The remaining units of the pattern and the rest of the moulding boxes were then assembled and rammed; on completion, the top box forming the riser was removed and rolled over for finishing, the remaining boxes being below floor level. When the pattern had been extracted, and the mould finished and thoroughly dried, the first main body core which weighed 3¼ tons, was located and set in the base of the mould. The precise setting of this core was important since in its construction twenty-four metal cups had to be accurately located for the internal setting of the twenty-four radial cores, each weighing 15 cwt, used to form the external ribbing for the ports of the filter. One by one sea sand radial cores, each having a metal dowel accurately located to fit the twenty-four cups, were assembled. An additional location at the outside periphery was provided at the bottom and top of the mould for the radial cores. The assembly of these cores, which had an additional location at the outside periphery, can be seen in the accompanying illustrations.

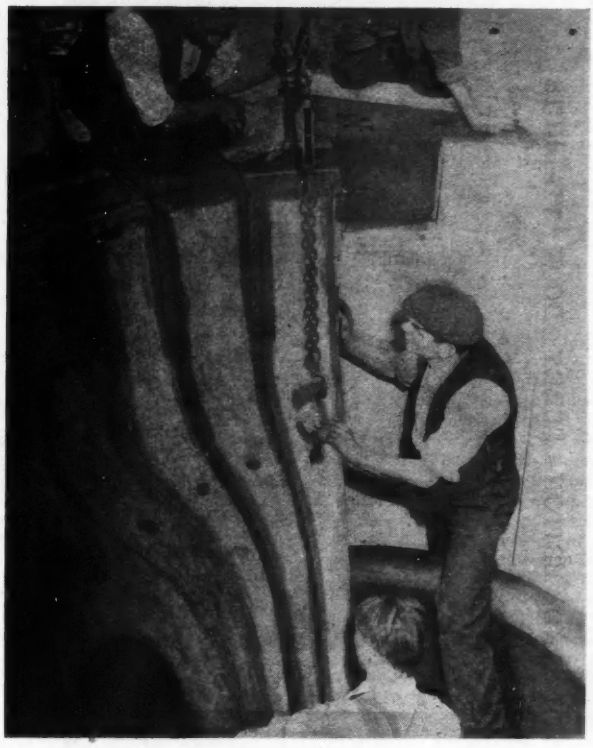
Four additional main body cores of natural bonded sand weighing an additional 6¾ tons, used to form the centre profile, were assembled and bolted with ¾in diameter bolts through the base core first assembled to the steel channels. This arrangement was adopted to eliminate risk of movement during the pouring operation.

Before the top box was finished and lowered into position, four 3in main down-gates were formed, each down-gate being connected to a channel runner around the outside of the mould at the joint face. From this channel were led twelve down-gates, each with four in-gates arranged at varying heights to alternate ribs on the periphery of the casting.

When the top moulding box had been assembled and clamped into position, two large "git" boxes were placed at opposite sides of the mould. The combined capacity of these boxes was 10,800 lb, sufficient to run the casting. Metal cups and plugs were used to close the outlets of both boxes until they were filled and sufficient metal was made available to ensure continuity of pouring into the mould. When, in the subsequent pouring of the casting, the metal reached the level of the top of the mould, additional metal from two 600 lb crucibles was poured direct into the open ring riser, to ensure adequate feed.

The metal used was melted in a reverberatory furnace and tapped into two ladles simultaneously, reserve metal being available in the two 600 lb crucible melters already mentioned.





RADIAL CORES BEING LOWERED INTO POSITION

The Institution of Mechanical Engineers

AT the Institution of Mechanical Engineers, last Friday, February 23rd, the following two papers were presented and discussed:—"The Size Effect in Fatigue of Plain and Notched Steel Specimens Loaded Under Reversed Direct Stress, by C. E. Phillips, Wh.Sc., M.I.Mech.E., and R. B. Heywood, Ph.D., B.Sc. (Eng.), A.M.I.Mech.E.; and "Some Fatigue Tests on Aluminium Alloy and Mild Steel Sheet, With and Without Drilled Holes," by C. E. Phillips, Wh.Sc., M.I.Mech.E., and A. J. Fenner, B.Sc. (Eng.), A.M.I.Mech.E.

The first paper describes how the fatigue strength under reversed direct stress was ascertained for specimens of various diameters in the range from 0·19in to 2·4in, the largest diameter being determined by the capacity of the machines available. Two steels were used in this investigation—a 25-ton mild steel and a 65-ton, 2½ per cent nickel-chromium steel. The specimens were either plain or notched (transverse hole) and, as far as possible, geometrical similarity was preserved with regard to the transition radii and the diameter of the transverse hole. A few fatigue tests on other types of notches, such as a circumferential V-groove and a shoulder, were also carried out. No intrinsic size effect with either material was observed with the plain specimens. With transverse-hole specimens in mild steel the fatigue limit was $\pm 8 \cdot 4$ tons per square inch for specimens of 0·33in diameter, and 6·1 tons per square inch for specimens of 1·7in diameter, thus showing that an appreciable size effect was present. A similar size effect was found with the alloy steel specimens containing a transverse hole, and fatigue limits of $\pm 17 \cdot 1$ and $\pm 13 \cdot 9$ tons per square inch respectively were obtained for these two sizes of specimen. It is suggested that the low values of fatigue strength reduction factors usually associated with mild steel as a result of laboratory tests do not apply in the case of the larger sections of this material commonly employed in engineering practice.

The second paper describes fatigue tests, under pulsating direct stress, of aluminium alloy and mild steel panels, with and without central holes, approximately 0·1in in thickness and up to 12in in maximum width. Comparison of the results of tests on panels of similar shape, but of different sizes, shows that larger panels are relatively weaker. The influence on the fatigue strength of varying the size of a drilled hole in a wide panel has been explored over a range of hole diameters from $^1/_{144}$ to ½ of the net width. While, in general, the presence of a hole causes a marked reduction in fatigue strength, the smallest holes result in only a slight reduction.

CONSTRUCTION OF THE RIVER NEATH AND BRITON FERRY DOCK VIADUCTS

MONOLITHS AND OPEN FOOTING—RIVER NEATH VIADUCT

CONSTRUCTION OF R.C. PIER—RIVER NEATH VIADUCT

CONSTRUCTION OF MONOLITHS

WEST ABUTMENT OF BRITON FERRY DOCK VIADUCT

Progress of the Neath By-Pass

THE construction of the viaducts over Briton Ferry Dock and over the River Neath, which form part of the Neath by-pass scheme, has now been in progress for about two years. Work on the foundations of the viaducts is well advanced and a start was recently made on the steel erection at Briton Ferry.

The Neath by-pass project, for which the Ministry of Transport is responsible, is a part of the London to Fishguard Trunk Road, Route A.48. The work now in hand comprises the south-eastern portion of the by-pass from Briton Ferry to Earlswood, where it will connect at a roundabout with the new Jersey Marine road (which is being built by the Glamorganshire County Council and the County Borough of Swansea), leading direct to the Swansea dock area. Together, these two roads will shorten the present 12-mile journey between Briton Ferry and Swansea by about half. The present contract provides for an eleven-span, all-steel viaduct, 970ft long, extending from a roundabout at Briton Ferry to Warren Hill, and carrying the road over the main London–Fishguard railway (Western Region), the Briton Ferry Dock, and the Briton Ferry Steel Company's sidings and offices. A short length of roadway will then be cut into Warren Hill, leading to a viaduct of sixteen spans of a total length of 1610ft, including a high-level bridge of 300ft clear span over the River Neath. The bridge is 90ft high above high-water level, and will permit the passage of shipping. This bridge and viaduct are being built of steel plate girders supported on reinforced concrete piers. The main bridge over the river is of plate-girder construction, comprising three girders, each having two anchor arms of 139ft 9in, two cantilever arms of 87ft 9in, and a suspended span of 124ft 6in. The other spans are of similar type. The general arrangement of the project is shown in the accompanying elevation.

The bridge provides for two 22ft carriageways, two 9ft cycle tracks, and two 6ft footpaths, making, with reservations, 90ft between parapets. The reinforced concrete deck slabs will be finished with a bituminous base course and wearing surface. The contract price was approximately £1¼ million, and time for completion three years. An idea of the steelwork design can be obtained from the typical cross sections which we reproduce. Riveted construction has been adopted.

The geology of the area consists of underlying steeply sloping beds of Pennant sandstone, the upper surfaces of which are very irregular owing to glacial erosion. Overlying the sandstone are glacial deposits, including boulder clay, of varying depths. On the River Neath saltings, these deposits continue to a depth of over 100ft below ground level, but in other places the rock appears on the surface.

The footings of the viaduct between Briton Ferry and Warren Hill have, in general, been taken down to hard gravel or rock strata. They have been constructed in the open, with the aid of timbering or steel sheet piling. Four cofferdams have been constructed at Briton Ferry Dock.

Inside the cofferdams, the piers have been founded on a good gravel stratum, and a common base has been constructed across the width of the bridge, three separate reinforced concrete legs being built up to take the anchor bolts for the steelwork. Where the footings are of lesser depth or have been founded on rock, however, three separate mass-concrete foundations have been built. These footings have been faced at the top with precast concrete blocks. The abutments at each end of this section, as also for the Neath River section, are of mass-concrete construction with roller bearings for the steelwork; 8 : 1 concrete was used for the abutments, with 4 : 2 : 1 concrete for facing, construction joints being brought out as an architectural treatment of the work, as shown in our illustration. All the concrete was weigh-batched, there being two concrete batching stations, one on each section of the job.

The open foundations described above for the section from Briton Ferry to Warren Hill have also been employed on the larger section of the work from Warren Hill to Earlswood, where the rock levels allowed, but in other places, owing to the great depth of the solid strata, two other methods have been used.

The two piers of the river crossing will each be founded on caissons sunk under compressed air. This work has been commenced, and the preparatory cofferdam on one bank of the river has been constructed. Eventually, six cylinders, each of 7ft internal diameter, will be sunk under each of the two piers, using compressed air, and then connected together by a reinforced concrete cap, with a steel sheet-piled surround driven into the river bed.

For the majority of the other piers on this section, however, reinforced concrete monoliths have been used for the construction of the foundations, there being one monolith under each leg of each pier. These monoliths each consist of a hollow box which is sunk into the ground by hand excavation or grabbing as circumstances permit.

The monoliths are 23ft 6in square, with outside walls 16½in thick, connected by 9in cross walls, to give four compartments, each 10ft square inside. They have a heavily reinforced cutting edge formed by tapering the walls to a thickness of about 3in. Generally they have been built 28ft high (i.e., in seven lifts of 4ft) and then sunk until a good bottom was obtained.

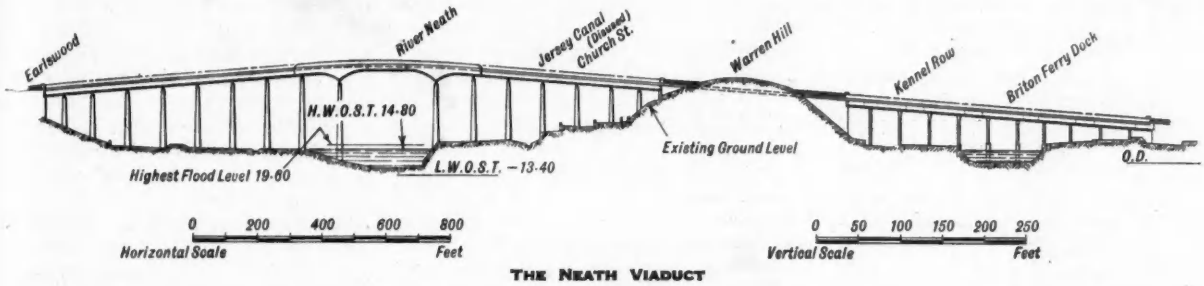
They are built in situ on a concrete erection base, which is afterwards broken away in sections before sinking is commenced. The illustration reproduced on page 286 shows this base in the foreground, with the shuttering and reinforcing steel for the cutting edge of a second monolith in place in the background. The concrete base is generally cut away in two stages—first the centre portions of each wall, then the parts left at the junctions of the walls. Sinking is then commenced, kentledge being added where necessary. So far some of the monoliths have been sunk to a depth of 30ft.

When the required depth has been reached the four chambers are each plugged with an inverted arch of plain concrete, followed by a seal of reinforced concrete. They are then filled with water and trimmed off as required at the top, where a substantial reinforced concrete cap is constructed. In general, the monoliths have been connected together in groups by ground beams to increase the rigidity of the completed structure.

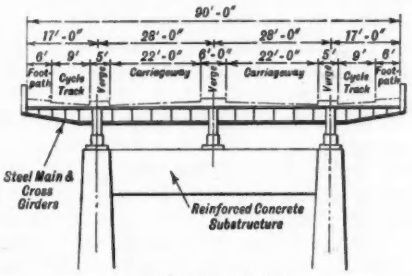
The reinforced concrete columns supporting the steelwork are then built up from the monolith bases. The accompanying illustration shows several monoliths at different stages of sinking, with an open footing for one of the piers also shown on the left. The top line of the steel sheet piling indicates the dip of the sandstone and the proximity of monoliths and open foundations gives a good idea of the irregularity of the rock surface.

Our illustration opposite shows the construction of one of the reinforced concrete piers in progress, the steel falsework being in position ready for building the portal beam. These beams are heavily reinforced and are 10ft deep. The columns are of massive appearance with vee grooves at regularly spaced construction joints.

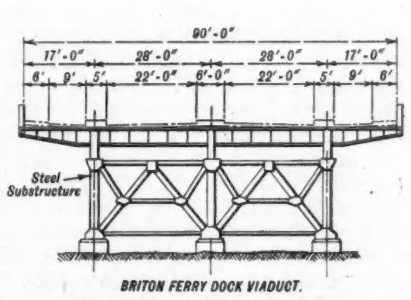
The Ministry of Transport's consulting engineers for the work described in this article are Messrs. Rendel, Palmer and Tritton, and the consulting architect is Sir Percy Thomas, P.P.R.I.B.A. The contractors are the Cleveland Bridge and Engineering Company, Ltd.



THE NEATH VIADUCT



RIVER NEATH VIADUCT



BRITON FERRY DOCK VIADUCT.

TYPICAL CROSS SECTIONS

BROCHURE ON ALUMINIUM ALLOYS.—The Aluminium Development Association, 33, Grosvenor Street, London, W.1, has prepared an illustrated brochure, entitled "The Use of Aluminium Alloys in Structural Engineering: An Introductory Survey." The brochure, which is available from the Association at a price of 2s. 6d., opens with a brief statement of the technical and economic case for aluminium in the structural field, and then gives examples ranging from the first aluminium bascule bridge to mine skips and cages. Aluminium base materials are classified and their properties described, with various tables of their mechanical characteristics. There are also brief notes on design and fabricating methods.

THE ENGINEER

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THE DEFENCE ESTIMATES

IN pre-war days the estimates for the armed forces gave the British taxpayer a comprehensive picture of the number of ships, aircraft squadrons, armoured formations and other forces required for the defence of this country and his views on the adequacy of our defence preparations, expressed through his Parliamentary representatives, had a considerable bearing on the estimates as finally approved. Many of our readers will remember in that connection the popular and successful clamour for more battleships in the early years of this century: "We want eight and we won't wait." But with the Communist menace has come a profound change, for the Russians publish no official information whatever about their armed forces—existing or proposed—and the British Government, with some justification, considers it essential to adopt the same policy as far as this is possible in a democratic country. The estimates for 1951–52, recently presented to Parliament, are on the same lines as those for previous years. "A number of new anti-submarine frigates are to be built," "there will be a further large increase in our day fighter aircraft strength," are examples of the kind of indefinite information to which we have now become accustomed. But they have the further disadvantage of being already out of date when published, for they are based on the Government's rearmament measures approved by Parliament in July and September, 1950. All three Service Ministers issue a warning in their memoranda accompanying the estimates that supplementary estimates will in due course be presented giving effect to the new rearmament proposals announced by the Prime Minister at the end of January. These revised measures will entail a total defence budget over the next three years of £4700 million—an increase of £1100 million on the sum approved last September. The Government has in fact already announced that the estimated cost of defence under the revised programme in the next financial year will be about £1300 million, compared with £1030 million asked for in the 1951–52 estimates and a total expenditure of £755 million, approved for 1950–51. The estimates of the Ministry of Defence, but not the Ministry of Supply, are included in these figures.

For all their shortcomings, the Defence estimates indicate very clearly that the Government has at last seen the red light and is now making up for lost time. As much as £56 million of the £85½ million increase required for the Navy over the original 1950–51 estimates (£193 million) are earmarked for shipbuilding, repairs, maintenance and armaments and we are assured by the First Lord that the whole programme is largely directed towards meeting the underwater menace of submarines and mines. As many anti-submarine frigates of new design as possible are to be laid down, the only limiting factor being the provision of machinery. The Army estimates (£418,800,000) are up by nearly £120 million on the current year, an increase which includes £76½ million for armaments and stores. Some two-thirds of the total expenditure under this heading is earmarked for the provision of tanks, and anti-aircraft and other weapons. Vote A provides for an increase of 60,000 officers and men. The Royal Air Force personnel strength, now 230,000, is to be increased to 270,000, but by far the larger portion of the increase of £105¾ million over last year's Air estimates (£223 million) is to be used for providing the additional aircraft and stores required for the expansion and re-equipment of the R.A.F. The Secretary of State for Air added "that the doubling of the front line strength of Fighter Command" had already been completed and that there was to be a further large increase in the day fighter strength. There is also to be a substantial increase in both Coastal Command and the night-fighter force, which is to be equipped with jet fighters. The customary table of the strength of the Fleet given in the First Lord's memorandum shows that there is a reduction of two destroyers, three frigates and ten submarines on last year's strength, the only addition during the current financial year being the surveying ship, "H.M.S. Cook." There are to be two types of new anti-submarine frigates, one simpler and cheaper than the other and, though lacking some of the refinements of the latter, still highly effective for anti-submarine work. The machinery for the first two of these ships of simpler design has been ordered and the hulls will be laid down shortly. There is also to be a third type of frigate "for other special duties," and work has already begun on two prototypes. It is, however, more satisfactory to have the First Lord's assurance that the conversion of destroyers into fast anti-submarine frigates is being pressed forward with all speed. Six of these vessels are being converted at the present time—the "Rocket" and "Relentless" are nearing completion—and the programme is to be expanded progressively during 1951–52. As in the case of anti-submarine frigates, it has now been decided that there are to be two types of converted destroyers—one being a kind of "semi-conversion," without the refinements of the other but with good anti-submarine qualities. H.M.S. "Tenacious" has already been taken in hand for this simpler form of conversion. In view of the delay in rearming there can be no doubt that the policy of converting destroyers is entirely sound. Since Russia has no battleship or carrier forces worthy of the name, the destroyer is no longer required to carry out the main function of attacking heavy ships for which she was designed. With her fast speed she is, of course, also an effective anti-submarine vessel, but lacks the equipment, endurance and economic running required for a good convoy escort ship; and it is this type of ship which we now need in large numbers because of the fast underwater speed of the modern submarine. More minesweepers of new design are to be built—orders for the majority of the forty-one minesweepers provided for under the September proposals have now been placed—and a programme of fast patrol boats and the building of a new hospital ship are in hand. Progress in the standardisation of material, technique and tactics with the United States and Royal Canadian Navies is satisfactory and already common methods of communications have been introduced. The re-equipment of our cruiser force is also well under way and the re-equipment of our carrier air groups with modern types of aircraft is being advanced as rapidly as possible. These are the highlights of the new naval programme and they make good reading, in spite of the absence of detailed figures. There is, however, still no information of the earmarking of merchant ships for convoy escort work or of the provision of material for their conversion into escort carriers.

The Army estimates contain little or no information on the subject of material and equipment, apart from Mr. Strachey's statement that 23,000 army vehicles had been rebuilt by the end of 1950, either under the

Ministry of Supply's programme or in Army workshops. This is clearly an important contribution to the immediate preparedness of the Army. The Air estimates are more helpful. The "Canberra" bomber is to come into squadron service this year and a large number of squadrons equipped with this type of aircraft are to be formed. "Washingtons" and "Lincolns" will in the meantime be the mainstay of our medium bomber force. The "Shackleton" is now coming into service with the Coastal Command squadrons: the run-down of Transport Command has been halted; a number of airfields are being built for use by American bomber groups in this country, which have now been joined by American fighters, and a Royal Canadian fighter squadron is at present training with Fighter Command. Both the Secretaries of State for War and for Air give encouraging news of good results from the improved conditions of service and higher rates of pay announced in September. No less than 10,872 of the 22,113 men who enlisted as regulars in the Army during 1950 entered after September 1st. Mr. Henderson gives no figures for the Royal Air Force, but refers to "a marked and very welcome impetus given to regular recruiting by the substantial increase in pay granted last year and by the higher rates of short service gratuity introduced at the same time." He is now very satisfied with the intake on short service engagements (three years active, two and a half years' reserve) but regards this method of entry as expensive in training costs and of little use for providing highly skilled and experienced tradesmen. He hopes, however, that the recently introduced trade structure, offering long service careers to the age of fifty-five, will do much to remedy matters. Apart from one or two of its branches, the Navy has never lacked recruits, but experienced petty officers and men have been leaving in large numbers since the war, after completing their first period of engagement of twelve years. It is presumably too soon to judge the effect of the increased scales of pay on re-engagements, for the First Lord said nothing on the subject beyond mentioning that the Navy is still short of senior and experienced ratings, especially at the petty officer level. The shortage is for the moment being met by retaining ratings beyond their terms of engagement and recalling men of the Royal Fleet Reserve.

LONDON'S TRAFFIC

Was there ever a time when the streets of London were not congested with traffic? It seems unlikely. For however far back we penetrate into history, to Victoria's reign, to the Georgian era, to the days of Shakespeare and beyond, we find critical references to the press of vehicles. In our day the problem of relieving congestion is only a new one because the internal combustion engine has so largely replaced the horse as a means of propulsion. But repeatedly since the engine began to oust the horse (if not before) the situation has been studied by authoritative bodies seeking a solution. Usually their recommendations have been expensive. In the Bressey Report, for instance—to go back no further than 1937—there were proposals for ring roads, for new and improved North to South arteries, and for a road tunnel under Kensington Gardens; and the more recent London Plan envisages equally large developments. Usually, again, little or no action has been taken to implement such proposals. In these days of stringent finance it is therefore a welcome change to find in the recent report of the London and Home Counties Traffic Advisory Committee proposals put forward that are so modest in nature, so moderate in cost and so likely to relieve congestion for some years ahead that we can wholeheartedly recommend that most of them be adopted with as little delay as possible.

There has, for years, been a tendency amongst some of those who have studied the traffic problems of large cities to claim that rebuilding of the streets would be too costly and that, therefore, the traffic permitted to enter the city should be limited to the maximum the existing streets can carry. It is refreshing to find so authoritative a committee as that whose report is now under review wholly rejecting such ideas. The Committee finds "there is every indication that the volume of traffic will continue to increase." Nevertheless, it has reached the general conclusion that "a reduction in the volume of traffic as a means of relieving traffic congestion is not only undesirable, but quite impracticable." To relieve the situation it makes a number of minor recommendations. It has found, for instance, that minor defects to traffic light installations occur more often than need be, and proposes more frequent inspection; it suggests the extension of permission to traffic to "infiltrate" around a left-hand turning and the barring of right-hand turns at a greater number of road junctions than at present. It is recognised that, even in streets in which other vehicles may not stop longer than is necessary to drop or pick up passengers, it is desirable to permit goods vehicles to stop for limited periods in order to load or unload. But it is proposed that, on certain short lengths of a small number of main thoroughfares and over short periods of the day, that facility should be withdrawn. The amount of horse-drawn traffic is falling rapidly and it is now considered that such traffic should be banned from a greater number of thoroughfares than at present. Study has been given to road repair works and the Committee feels that co-ordination amongst the statutory undertakers (gas, water, electricity, &c.) and road authorities could be improved. It recommends that "undertakers in London should review their present arrangements at a high level with the object of producing a comprehensive system of joint consultation and programming of their works." This is all "small beer" enough. Yet such minor changes, when added together, can still amount to quite large improvements. The Committee, moreover, puts its fingers on a more considerable trouble when it refers to the parking problem. Census figures are quoted to show that in parts of the inner area no parking accommodation is available off the roads for up to 50 per cent of the number of vehicles parked. The excess necessarily occupies space that should be available for traffic flow. It is therefore recommended that there should be an immediate survey to ascertain what off-street sites for parking places are likely to be available in the future, and that "car parking space should be regarded as an essential part of any new block of offices or other commercial development and . . . that planning control should be exercised . . . to ensure that it is provided." It is considered that "a bold policy of providing car parks in Central London would, in the long run, be economic." In all this the Committee has had it very clear in mind that not much money can be expended. It remarks sagely, "The relative cost of car parks and road improvements must be considered; £5,000,000 spent on the provision of car parks . . . would give very much greater benefits from the point of view of relieving traffic congestion than the expenditure of the same sum on road improvements."

It can, of course, be truthfully claimed that all the measures proposed by the Committee are minor ones and that a complete solution to London's traffic problems must await the expenditure of great amounts of money upon the building of new streets and the widening of old as suggested in so many previous reports. Yet in studying the present report it should not be overlooked that for the past thirty years traffic in London has been kept moving far more as the consequence of continuous minor improvements, such as those suggested, than of major ones. Progressively the gradual adoption of one-way streets and roundabouts, the installation of traffic lights, the banning of horse traffic, the prevention of parking in main thoroughfares, together with minor improvements at road junctions and widenings here and there has adapted streets to carry more traffic. Nor has the possibility of improvement by such inexpensive means yet ended. The theoretical capacity of a 10ft traffic lane approaches 2000 vehicles an hour. Yet observed flows at times of dense traffic seldom exceed 600 vehicles per hour. Those figures suggest that there still remains scope for the removal of obstructions to traffic flow and for the improvement of road junctions. Piecemeal, stop-gap measures to relieve congestion have been successful in London for the past thirty years and more. Certainly they cannot be expected to be successful for ever. But in the shorter run they can still be depended upon to provide relief.

Obituary

W. H. McALPINE

Mr. William Hepburn McAlpine, whose death occurred on February 20th, at his home at Henley-on-Thames, at the age of seventy-nine, was the eldest surviving son of the late Sir Robert McAlpine, Bart., the founder of the firm of Sir Robert McAlpine and Sons and the group of building and civil engineering companies associated with it. He was born at Motherwell, Lanarkshire, on October 31, 1871, and was educated at Ayr Academy, Ayr. On leaving school in 1887 he entered his father's business, and before long, although only a young man, had taken upon himself its financial control, a control he retained and exercised with outstanding ability in building up the firm to be one of the leading contractors in the country. On Sir Robert's death, Mr. W. H. McAlpine became chairman of the company. Of the many works with which he was associated,

those which he considered the most noteworthy were the Methil dock on the Firth of Forth, constructed about 1910; the new entrance lock and dry dock at Tilbury, 1928; and the Southampton quay wall in 1930.

His interest in the advance of medical science was great, and he and his brothers were responsible for the financial side of the establishment of the Neurological Department at the Middlesex Hospital. The Physiotherapy Department at East Surrey Hospital, Redhill, was also his gift. In 1898 he married Margaret Donnison, daughter of the late Thomas George Bishop, and there were two daughters and three sons of the marriage.

As we go to press, we have learned with regret of the death of Sir James Scott Pringle, K.C.B., formerly Director of Electrical Engineering at the Admiralty, which occurred in London on Tuesday last, February 27th. We note also with regret the death, on February 27th, of Sir Percy Malcolm Stewart, Bart., president of Associated Portland Cement Manufacturers Ltd., and Commissioner for Special Areas from 1934 to 1936.

Literature

Joint Consultation Over Thirty Years—A Case Study. By C. G. RENOLD. London: George Allen and Unwin, Ltd., 40 Museum Street, W.C.1. Price 18s.

THIS book is the record of Sir Charles Renold's own experience of joint consultation over the past thirty-two years. It opens with a short history of the company, traces the growth and development of joint consultation at the Renold works at Manchester and at the Coventry, Cardiff and Calais works, discusses consultation in the ranks of management, describes some typical problems and finally evaluates the experience. The main text is followed by some seventy-four pages of appendices in which working documents and minutes of meetings are given.

The book is an impressive record of pioneering achievement and it is quite startling to find that management attitudes towards consultation, which to-day are considered enlightened, were accepted almost as commonplace in the Renold Company more than thirty years ago. When in the very early days of joint consultation in 1917 difficulties were found to be created in the relations between middle management and shop stewards because higher management had face-to-face contact with shop stewards and superintendents were not represented, " . . . a meeting took place between all superintendents and all shop stewards without any of the higher management present . . ," and as a result of this and other meetings all ranks of management were included in the joint consultative structure. In the same way, the Renold management seems to have recognised very early on that good management organisation is a basic condition for successful joint consultation. Parallel with the development of consultative procedures, it instituted large-scale management reorganisation with regular meetings throughout management with decentralisation of managerial responsibility and authority. This development led to serious attempts to sort out management roles and relationships and to the recognition of the dangers to good management of the unrecognised carrying of multiple roles by individuals. The difficulty experienced by many growing companies when working directors exercise their directorial power and authority in managerial positions seems to have been largely avoided. Sir Charles is insistent that joint consultation in the Renold companies arose from no theoretical democratic ideal, but from the needs of the immediate situation and the problems it presented. He does not add that there must have been considerable insight into the needs of the situation.

The book is a case study, but it is a case seen through the eyes of the man who, for a great part of the time over which the experience extends, was a leading figure and prime mover in the establishment and development of joint consultation. In the earlier chapters he refers often to the strong and dominating personality of Hans Renold, his father, and founder of the company, and suggests that the changes in management attitude and behaviour were made necessary by the growth of the company beyond the control of one man. He then describes the changes that took place rather as though acceptance of this necessity led to the organisational changes which took place; but the impression gained from reading the book is that one strong personality was replaced by another, a different personality, perhaps, but still one which could make its presence felt. The case histories quoted all show rational solutions to typical industrial problems, but one cannot help wishing that there was an account of more follow-up and a more detailed investigation of the attitudes of those involved in the discussions. Elsewhere, too, as when Sir Charles insists rightly on the need for a coherent and consistent management policy, but adds as an inevitable corollary that management must speak with one voice, one feels that one would like more evidence that the coherence and consistency are not more apparent than real. In consequence, the evaluation of the experience is not so convincing as it might be, and a more systematic evaluation would have added to the value of the study. As it is, before accepting the evaluation, one feels one would like far more evidence than is available, and about other things besides joint consultation. There is, for example, the problem of redundancy caused at Manchester by the transfer of part of the work to Cardiff, which is given as one of the typical problems. The statement that " The department was closed down in January, 1948, without hard feeling " is hardly adequate evidence as a conclusion to what precedes it, and that there were no hard feelings must undoubtedly have depended on more than the joint consultative procedures which are described.

Sir Charles Renold has done a service in writing this case history. It is to be hoped that he will be encouraged to tell more of the story of the growth and development of the company with which he is associated, giving himself a broader canvas than joint consultation.

Theory and Design of Electron Beams. By J. R. PIERCE. London: Macmillan and Co., Ltd., St. Martins Street, W.C.2. Price 26s. net.

THIS book is published as one of the Bell Telephone Laboratories Series. The author has been a member of the technical staff of the Bell Telephone Laboratories since 1936, where he has worked on various vacuum tube problems. He is writing currently in the *Bell System Technical Journal* on " Travelling-Wave Tubes." His book on the " Theory and Design of Electron Beams " deals with beam formation and focusing as is required for such tubes and other electronic devices. As stated in the Preface, it excludes consideration of beams required for electron microscopes and image tubes; accordingly, there is little on the subject of aberrations. With this limitation the book constitutes a comprehensive treatise on the fundamentals of electron optics.

Dr. Pierce's treatment is to obtain the paraxial ray equation which describes the motion of electrons making small angles with the axis of symmetry in electrostatic and magnetostatic fields. Two-dimensional fields and fields with axial (cylindrical) symmetry are considered. The equation is shown to be a second order linear differential equation with constant coefficients. The action of magnetic and electric lenses is obtained as solutions of the differential equation. Examples are given where analytical solutions are possible and it is shown how numerical integration can cover other cases.

In order to derive the paraxial ray equation the author starts from first principles. The fundamental properties of electric and magnetic fields are considered in the first chapter, which serves to explain the system of units and the notation that has been adopted. Equations of motion for an electron in certain field configurations are obtained, and solved in a few cases to give a description of the motion. General relations which are required in the subsequent analysis are then derived.

A descriptive chapter explains with some good photographic illustrations, electron path plotting by means of rubber sheet models and the use of an electrolytic tank in potential mapping. Automatic plotting of electron paths is referred to, but not described.

In the first part of the book the effects of thermal velocities and space charge are ignored, as is usual in most treatments. They are afterwards, however, both very fully considered. Expressions are derived for the limitation in current density imposed by taking into account the velocity of emission from the cathode. They are applied to the design of a cathode-ray tube. Modification of the paraxial ray equations due to space charge is investigated, and examples given of both exact and approximate solutions. A chapter on " Electron Guns " shows how the theoretical results previously derived can be applied to design.

In his concluding chapter the author cautions the reader that the book " presents not all possible material concerning electron beams, but mainly, only such material as can be treated mathematically." The mathematical character of the book is shown by the facts that 160 equations appear in the first four chapters, and 300 in the rest of the book. In the first part of the book the mathematical treatment is largely straightforward. Most of the intermediate steps in the analysis are given and a very logical order is used. Some readers will meet an initial setback since on the fourth page, in equations (1.9) and (1.10), expressions are written down for the potential in axially symmetrical and two-dimensional electric fields. It is not at once made clear that these are solutions of Laplace's equation, although expressions for Poisson's (or Laplace's) equation in cylindrical and rectangular co-ordinates are given in a useful appendix on " Vector Relations." Something more on the subject of Laplace's equation, which is such a fundamental feature in the theory of electron optics, appears necessary.

There are many cases in which the under-

standing of the mathematical analysis would be facilitated by a diagram. They would, for example, assist in the following cases :—"Crossed Electric and Magnetic Fields," on page 26 ; "Radius of Curvature" on pages 41 and 42 ; "Two-Dimensional Fields" on page 88.

The symbols and notation are, with few exceptions, standard and present no difficulty. It is noted that ψ is used for both magnetic—equations (4.20) to (4.24)—and electric flux—equations (4.38) to (4.42). It would be preferable to use separate symbols, ψ for electric flux, ϕ for magnetic flux. In equation (4.38) the electric flux/unit depth is written as $d\psi = E_R ds$, intead of $d\psi = D_R ds$ or $\epsilon E_R ds$. There is an error in connection with magnetic flux when the unit of flux density in the M.K.S. system, which is used throughout the book, is incorrectly given as webers/meter instead of webers/meter^2 in equations (1.22), (1.26) and (1.27). Since 1 weber/meter^2 = 10^4 gauss the conversion factor in (1.26) is inverted, although (1.27) is correct.

There are a number of small errors in the equations and diagrams ; some are trivial misprints, others may cause slight difficulty in following the analysis. There are also occasions when, in describing mathematical operations, reference is made to the wrong equation. For example, in obtaining equation (4.8) reference is made to differentiating (4.3) and (4.4) instead of (4.1) and (4.2). As a small point of detail sin θt, cos θt and tan θx, which occur in equations (3.7) to (3.11) would be better written $t \sin \theta$, $t \cos \theta$ and $x \tan \theta$ respectively.

The book is very well produced and, in particular the numerous equations are clearly set out, as also are the diagrams, sketches and photographs. The table of contents gives easy reference to the subject matter covered. A short bibliography is included. The minor errors which have been noted do not detract from the value of the book as a whole. It can be considered to serve two purposes. First, it provides a textbook on the fundamentals of electron optics as applied to the focusing action of electric and magnetic lenses. The inclusion of problems at the end of each chapter increases its usefulness in this respect. Secondly, it gives a thorough treatment of the subject for the design engineer, who is concerned with all the factors which influence performance and the application of theoretical analysis to provide design data. Dr. Pierce, in collecting together theoretical material for his own use, has not only produced a book for the specialist, but a valuable reference textbook for all engineers with an interest in electron optics.

Railway Expenditure and the Volume of Traffic. By W. A. TIMMERMAN, D.Com. London : The Locomotive Publishing Company, Ltd., 88, Horseferry Road, S.W.1. 25s.

AT the present time the subject of railway expenditure is a very live topic. On the one hand, there is the "freeze" imposed by the British Government, while the attention of industry is concentrated upon goods for export ; and, on the other hand, there is the colossal expenditure of the American railways. In the face of imposed restraint or, alternatively, a swollen expenditure bordering upon a gamble, it is extremely difficult for the student to deduce any law between annual expenditure and traffic receipts, or, for that matter, with any other criterion of accounting. For this reason particular interest is attached to a study of the subject by Dr. W. A. Timmerman, using the South African Railway as a basis. The difference between the pressing day-to-day matters with which all who are concerned with the design, construction and maintenance of railway plant are so deeply interested, and Dr. Timmerman's academic and detached, though masterly analysis, in which all costs —running, maintenance and administration —are tabulated, is, of course, profound, and largely due to the nature of the approach to the subject. In selecting railway expenditure as a subject for a thesis to be submitted to the University of Pretoria for the degree of Doctor of Commerce, the author chose to challenge the statement of the South African Railway that a large proportion of the total transport expenditure consisted of constant costs. For "general inquiries into and experiments with the data published invariably gave the impression from graphs drawn and calculations made that the fixed costs formed only a small part of the total costs." The careful analysis subsequently made and reported in this book fully supports, at least in the author's view, his original impression. The appearance of the book is particularly appropriate at a time when the British Transport Commission is attempting to produce a co-ordinated system of transport charges for road and rail services. For if the author's contention was borne out for British Railways by that comprehensive and efficient costing system that he recommends for adoption, the influence upon the railway rates structure might be large and the co-ordination of that structure with road rates might be facilitated.

The author is to be congratulated, not only upon a successful thesis, but upon the publication of a mass of statistical information that, we feel sure, will be of value to all interested in the administration of railways.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

ENGINEERING INSTITUTIONS

SIR,—In two recent issues of THE ENGINEER you have published letters by correspondents who are making a plea for unity in the engineering profession. It is suggested that there should be a merger of the various institutions into the Institution of Civil Engineers, but it is doubtful, even if this were practicable, whether the huge organisation which would be the result of such an amalgamation would be in the best interests of the engineering profession as a whole.

There are three fundamental kinds of engineering, viz., civil, mechanical and electrical, and all specialised branches are limited fields of one of these broad divisions. For example, in railway work, the design of the permanent way, with its bridges and tunnels, belongs to the civil engineering category, whilst the design of locomotives and rolling stock is basically in the mechanical engineering sphere. In road transport, both mechanical and electrical engineering are embodied in the design of vehicles. As a further example, the design of aircraft embodies all three types of engineering. Fuselage design comes under civil engineering in a specialised form ; aero-engines and mechanically and electrically operated accessories constitute special applications of mechanical and electrical engineering. Thus, the three existing major Institutions cover the whole field of engineering and each of the smaller specialised bodies should be merged into the most appropriate of the three major ones. This merger could probably be done in a manner which would avoid causing unemployment of the existing staffs of the smaller bodies, as the enlarged senior institutions would require additional staff.

After such a merger, the public would then only have to remember three engineering qualifying letters, instead of about fifteen or more. Most people either forget the lot or pay homage to the letters A.M.I.C.E.

At a Conservative Association meeting just before the last Election, an accountant explained to the audience that there were three kinds of engineers, civil, mechanical and electrical—he was in the course of discussing a letter by an engineer, appearing in the local Press. Accountants are valuable members of the community, and I think the above reference to engineers by a member of another recognised profession is worth consideration.

Any such group merger as outlined above would not, of course, interrupt the work of the Engineers' Guild.

EUSTACE TRILLO

Cheltenham, February 26th.

TURBINE NOZZLES

SIR,—I beg to refer to the January 26th issue of THE ENGINEER. On page 130, in the article "Reactive Force in a Turbine Nozzle," the following expression

$$2P \times \frac{\frac{\gamma}{\gamma+1}\left(\frac{2}{\gamma+1}\right)^{\frac{1}{\gamma-1}}}{1-\left(\frac{2}{\gamma+1}\right)^{\frac{\gamma}{\gamma-1}}}$$

can be appreciably simplified, i.e.,

$$P \times \frac{\gamma}{\left(\frac{\gamma+1}{2}\right)^{\frac{\gamma}{\gamma-1}} - 1}$$

JOHNNY SCHÖNNING

Stockholm, 80, February 7th.

The Canadian International Trade Fair

THIS year's Canadian International Trade Fair is to be held from May 28th to June 8th at the Exhibition Park, Toronto, and applications for space already received from United Kingdom manufacturers have reached a total of nearly 70,000 square feet. The Fair, of course, offers an excellent opportunity to display British goods to North American markets, and most of the British exhibits are being organised by trade associations in this country.

The organisers of the Fair report that the British machine tool industry—whose stand last year was a prominent feature of the Fair—will have an exhibit occupying half of the remodelled Industry Building. This display, which will be the largest single exhibit in the Fair, is to be provided by member firms of the Machine Tool Trades Association, the National Federation of Engineers' Tool Manufacturers, and the Federation of British Hand Tool Manufacturers. Then there will be a joint exhibit by firms belonging to the Scientific Instrument Manufacturers' Association. It will include instruments required for industrial, medical and research purposes, and will, naturally, demonstrate current trends in British design. The British Industrial Truck Equipment Group and the Mechanical Handling Engineers' Association are other organisations which propose to participate in the Fair, and their members will show an extensive range of materials handling equipment in the Automobile Building. Some space has also been taken up by makers of printers' machinery, while a newcomer to the Canadian Fair is the British Clock and Watch Manufacturers' Association. Member firms of that Association are arranging a comprehensive collection of clocks and watches, including those made specially for industrial use. Another important exhibit from the United Kingdom will be that of the electrical engineering industry.

The Fair is organised by the Canadian Government Exhibition Commission, which has a London office at Canada House, Trafalgar Square, S.W.1.

Investment Castings—Their Design and Limitations

By D. F. B. TEDDS, A.I.M.

FOR shapes and alloys that are difficult to form by other production methods, the investment casting process fills an important gap for engineers. Although much has been written in the past five years about the lost wax investment process, it has mostly related to the process itself,* and has been designed to help foundrymen over the various stages of the technique. Little has been said which can act as a guide to the designer, and it is proposed to outline the advantages and commercial limitations of the process in order to clear up any uncertainties that may exist regarding this process.

Design Considerations

Before going into details of the various design factors involved, one or two points must be borne in mind. When the investment casting process is being considered as a means of producing a particular component, it is best to consider it whilst in the drafting or designing stage. In the past, the precision caster has been asked to produce components specifically designed for another process, and this does not lead to the best results. The designer can do much to help the founder and consultations in the early stages can solve a number of problems to mutual advantage.

The second point which must be mentioned is that the investment casting process can be utilised to produce three different classes of component.

(1) To produce precision castings. This entails the production of small size castings to close dimensional tolerances. Precision casting limits must be judged against other casting process limits. It is a fallacy to judge it against machining tolerances, which can be controlled to 0·0001in *ad lib*. Casting tolerances cannot meet that figure owing to the many variables involved, e.g., variations in the refractory materials used for making the mould; variations in the composition of the metal cast; discrepancies in metal temperature, &c.

(2) To produce castings of thin cross-section, and large surface area. These castings do not come into the category of "precision casting," since they cannot be produced to such close dimensional control. They are in direct competition with sheet metal manufacture and offer certain advantages over their rival in that they are one complete homogeneous unit, and as such are structurally stronger.

(3) To produce castings of heavier section by gravity casting techniques. A number of castings can be made by the investment process, which are reasonably close to dimensional tolerances, and have a superior surface finish to those produced by normal foundry methods.

Design Factors

Weight.—There is no minimum limitation on weights. The smallest part made to date weighs 1gm (i.e., $^1/_{28}$ oz). The maximum weight of a part is dependent upon the dimensional requirements and the capacity of the equipment available at various stages of the process. The maximum weight of castings produced to precision methods is approximately 5 lb. Castings of thin section have been produced weighing up to 53 lb. Gravity cast components are possible in excess of this figure.

General Wall Sections.—The general wall thickness depends upon the adjoining sections, the area of the wall and the distance the molten metal has to travel in the mould. Normally the minimum wall thickness practicable for production is 0·060in, but thicknesses as small as 0·030in have been done successfully on small components. Quite often it is not a question of being able to

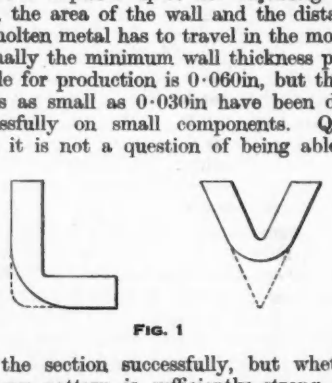


FIG. 1

cast the section successfully, but whether the wax pattern is sufficiently strong and rigid to withstand the vibration during moulding operations.

Coupled with the problem of wall thickness is the question of changes in section. Just as in the conventional methods of casting, abrupt changes of section in a precision investment casting are to be avoided. When liquid steel solidifies it contracts about 3 per cent in volume and since steel solidifies progressively from the mould surface towards the centre of the mould cavity, a pipe or contraction cavity will result unless the section is fed from some reservoir containing liquid steel. Thin sections adjoining heavy sections are difficult to feed and will probably suffer from

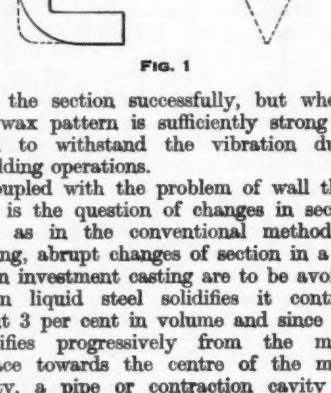


FIG. 2

shrinkage cavitation. Castings with defects of this type under vibratory stress aided by stress centralisation may develop cracks extending from the cavity to the casting face. If the casting is to operate under gas or fluid pressure, then leakages may develop.

In order to assist the designer to appreciate the foundryman's problem, the following points are made:—

In designing any joining sections all sharp corners at the junctions should be replaced by radii. These should not be too large, since an increase in metal mass can lead to extensive shrinkage cavitation. Unfed joining sections in "L" or "V" shapes can have a generous outer radius so that the section becomes slightly smaller than that of the arms (see Fig. 1).

In designing sections that join in a "X" section it is suggested that two of the arms be off-set considerably or, if possible, cored out in order to reduce the mass effect.

"T" and "Y" sections may also be modified in an effort to reduce or eliminate contraction cavitation (see Fig. 2).

As distinct from normal foundry practice, the investment casting technique does not lend itself to selective chilling of heavy sections, which assists in balancing the freezing rate of the molten metal, and so minimises the formation of contraction cavities. Thus, the question of coring out heavy sections in order to reduce the mass effect should be practised wherever possible in an effort to even out the general wall thickness. The coreing can completely hollow out a section (see Fig. 3a) or only partially reduce it (see Fig. 3b).

Ribs.—It may be pointed out in connection with joining sections that it is the custom of designers to use webs, brackets and ribs between various parts of the casting to impart a certain amount of rigidity or stiffness to the casting. Such stiffening members should be kept to a minimum as they are sources of considerable trouble both to the formation of hot tears and shrinkage cavities. Should it be imperative that they form an essential feature of the design then extensive coreing of the bracket in the region of the adjoining section should be carried out. Such coreing will not impair the stiffening features of the bracket, and will at the same time allow for better conditions of homogeneity of the adjoining sections.

Taper or Padding.—It is often of considerable assistance to the foundryman if certain sections can be given a generous taper and the excess metal removed as a machining operation, e.g., if owing to the particular design, a "T" section of approximately 0·25in thick and 6–8in long, were cast on-end, then considerable difficulty would be experienced in producing a sound section owing to the length the molten metal has to feed. By giving a generous taper from the remote end to the feeder a sound section is assured and if situated on one side only, then the machining operation is simplified (see Fig. 4).

Edges.—The minimum practical edge thickness is considered to be 0·010in–0·015in, provided there is a gradual tapering rather than an abrupt change in section. A typical example is the turbine blade. It is possible to cast almost a feather edge, but scrap rates are increased due to damaged wax patterns and mis-run castings.

Holes.—Holes can be readily cast to any desired shape, especially if it is a clearance hole, oil or air passage, loose fit, &c., but various considerations must be given. The size of hole is important and generally speaking the smaller the diameter the more difficult it is to cast. Length of hole is also important, since as the length increases so do the production problems. If the hole is to have close tolerances then it is best finished by normal machining methods. The location of the hole is also important and it can best be judged by the founder whether it can be moulded *in situ*, whether special coreing is possible or whether it is best machined as a final operation.

Threads.—It is recommended that threads should not be cast as a general rule, especially those of fine-pitch, since dimensional shrinkage allowances must be compensated for and any slight error in pitch which occurs is cumulative. Die costs are also prohibitive and, as external threads usually have a part-line and therefore have to be chased on a machine, it is more economical to

* See, for instance, "The Lost Wax Process of Precision Casting," J. S. Turnbull, Proc.I.Mech.E. Jan. 6, 1950.

machine, tap or grind threads on the resultant casting.

Fillets.—Fillets are advantageous from a stress standpoint and are also helpful to the founder. They can be fairly generous, at least $^1/_{32}$in being necessary and quite often $\frac{1}{16}$in is not too much. The main point which must be borne in mind is not to increase the volume of metal too much at a change of section as this can bring shrinkage cavitation problems to the foundryman.

Draft.—An important point that the designer should take into account when considering the lost wax process is that the wax pattern must be removed from a die without distortion. This requires draft or draw on those surfaces perpendicular to the parting line of the die. It should be as generous as possible, one degree per face being usual with a minimum of $\frac{1}{2}$ degree per face.

Undercuts.—Undercuts or negative angles, whilst undesirable as in most methods of manufacture, can be cast successfully as a general rule. They increase the cost of die production since split cores or loose pieces have to be employed in order to produce them in the wax pattern. Also wax pattern production is slowed down and pattern breakages, when extracting from the die, can be expected to rise.

Process Limitations

Having discussed the various factors appertaining to the designing of precision castings, it is now proposed to outline, in the light of past experience, some of the limitations the process reveals.

Surfaces and Soundness.—The final operation before dispatch of all precision castings is to shot-blast at relatively low pressures (10–30 lb per square inch), using fine-grade steel shot. This gives a fairly smooth, matt finish to the casting. The surface condition of the original wax pattern also assists the quality of the surface finish. Any surface imperfections at that stage are reproduced in the final casting. Another factor affecting the resultant surface finish is the primary coating applied to the wax and forming the facing of the mould cavity. Patterns not completely covered and allowing the coarse moulding material to be close to the pattern face will have a rough, scabby finish in that particular spot.

A problem often confronting the precision casting foundryman is the question of large surface areas, which lie in the horizontal plane during the moulding or investing of the wax pattern. Such surfaces tend to trap air pockets and also to be poorly supported by the investing material on the underneath side. This means irregularities in the surface of the resultant casting, which can only be cleaned subsequently on the fettling bench or by machining. If these surfaces can be relieved by a series of holes without detriment to the performance of the casting a more consistent result is obtained.

Pits and bumps are also likely to be present on the casting when removed initially from the mould. Minor surface flaws are removed by hand grinding, filing, &c., but whilst surface blemishes are acceptable for many components, they are intolerable on others, e.g., turbine rotor blades.

While the majority of castings can be made sound by complicated gating and feeding techniques, padding and taper, &c., economies can be effected by the use of simpler foundry practice provided minor internal shrinkage cavitation is not objectionable. For stressed parts, internal soundness is a prime requisite and 100 per cent X-ray examination is called for. For many types of components, minor internal shrinkage is not detrimental to the performance of the part and co-operation between designer and foundryman can do much to alleviate production problems so that they fall into line with performance requirements.

Warpage.—Some castings, depending upon their size and shape, tend to warp considerably. Generally the longer and thinner the

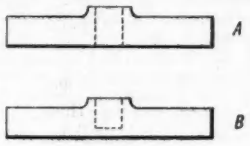


Fig. 3

sections and the softer the alloy used, the greater the tendency for warpage, and allowances must be made for finishing the casting. It is sometimes necessary to straighten castings and here the softer alloys are an advantage since, while they are more subject to distortion, they are straightened more readily than sections made in harder materials. Also certain circular components or holes may not be produced correctly to shape and size. This is influenced by the various sections of metal in the vicinity of the hole or even the position of the gates and runners. Thick or thin sections around a hole, and gates, runners, &c., all form hot spots with varying cooling rates, which set up casting stresses, thus distorting the casting by pulling unequally in one or more directions. It is often necessary to gate into one or more places on a casting, and it is not always possible to predict in advance where the gate should be located for obtaining the best casting results although a good general guide can often be given.

The designer must indicate those surfaces where gates are least desirable, and the areas which will require finish grinding or machining or which will not interfere with the function of the part if it does not have subsequent machining operation performed on it.

Tolerances.—This is probably the most discussed and the most difficult topic relating to investment castings. There are a

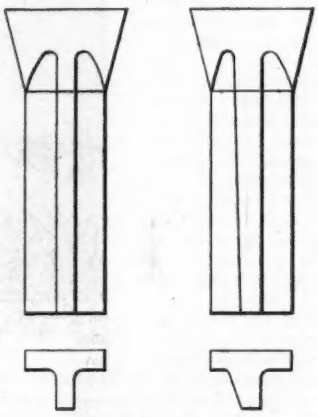


Fig. 4

number of factors, as already mentioned, which influence the tolerances possible on a particular casting.

One of the main problems confronting the precision caster is deciding upon dimensional shrinkage allowances when producing the die for wax pattern manufacture. Some faces and sections, which are free to contract in all directions, will shrink the full amount, i.e., 2–2$\frac{1}{2}$ per cent. If any restrictions are present then the shrinkage may amount to only 1$\frac{1}{2}$ per cent.

Similar factors also influence the shrinkage characteristics of the casting. Other points which also have a bearing on the dimensional tolerances possible are :—

(a) Position of gates, which form hot spots in the mould and, owing to their mass, tend to pull the casting out of shape.

(b) Composition of refractory material used for the mould—this will vary in both chemical composition and grain size no matter how strict the technique control, and will have some influence on the results obtained.

(c) Casting temperature—it is difficult to control this to within $\pm$10 deg. Cent. of the temperature desired, and generally speaking the higher temperatures produce greater variations.

It can be realised that to consider tolerances of $\pm$0·0005in or even $\pm$0·002in is almost out of the question. On castings of reasonable dimensions (2in to 3in) a commercially practical proposition is $\pm$0·005in. To be able to talk in tolerances of $\pm$0·005in on small steel castings is an achievement in itself, but, as mentioned earlier, to consider its precision with machining tolerances is rather ambiguous.

It is important for the designer to understand this and appreciate the difficulties encountered by the foundryman. The tolerances that are placed on a drawing should be only those which are essential.

Cost of Process

Finally, a word or two on the cost of this process in order that the designer may make some comparison with other processes of manufacture and assess the true worth of precision castings.

The most important items which have to be considered are :—

(1) The cost of the injection die.
(2) Moulding material costs.
(3) Metal cost.

Die Cost.—The cost of producing low melting point metal dies will vary, quite naturally, with the intricacy of the component, and whether or not a master metal pattern has to be produced initially. Assuming the component is of comparatively small size, a pattern is available, and it can be made in a two-piece book-type die. The cost to produce such a die is only in the region of £10–£20.

Should a larger and more complicated casting be required with close dimensional tolerances, then a machined die is warranted, which may cost hundreds of pounds to produce.

Which method is finally adopted is dictated largely by the design requirements, size of component, number of components required, &c.

Moulding Materials.—This part of the process is the next most expensive item.

The mould or investment is compounded from refractory materials bonded with a solution containing condensed tetrethyl silicate and methylated spirits. These, at current prices, are 30s. to 35s. and 2s. to 3s. per gallon, respectively.

The quality of the refractory material used varies with each manufacturer, but is in the region of 10s. to 30s. per cwt., and after being used for producing a mould it is usually discarded.

The bonding solution varies slightly in the ratio of ethyl silicate to methylated spirits, but at the prices quoted it costs approximately 14s. 6d. per gallon. This solution is mixed with the refractory in a ratio of about 22 lb of sand per gallon of solution to produce a small mould 6in-7in dia. by 8in-10in high. Thus, the basic cost of a small mould in material alone is approximately 17s. 6d. Economy in moulding

materials can be effected by casting as many components in a mould as is practicable. This may vary from one to three or four hundred, depending upon their size, thus spreading the cost of the mould materials over a number of components, and reducing their cost accordingly.

Metal Cost.—As the mould is really an expensive tool, which can only be used once, there is little point in casting low-cost materials, such as mild steel or cast iron into it.

Most of the steels cast are of special alloy composition, stainless, heat-resisting, abrasion and wear resisting types. These can vary from 2s. 6d. to 25s. per lb, and it depends again upon the design requirements, which type of material is used.

From these few remarks it will be realised that precision castings are not produced at so much per ton or even so much per pound. Each component has its own individual problems, which can only be decided upon by co-operation between designer and foundryman.

The precision casting process has a definite place in industry. In comparison with such methods as practised on capstan lathes, investment casting employs a much higher proportion of labour and it can seldom compete with any machining methods where long runs are involved on suitable steel parts. For small runs or when designs are still experimental, it can often compete because of its lower tooling-up charges. Where parts are too complicated or the alloys required are difficult to machine, investment casting very often offers important economies and is probably the only practical means of production.

It should be remembered that investment casting became of industrial importance because of its ability to produce large quantities of small parts accurately and economically from alloys difficult to fabricate by pre-existing methods. Its advantages diminish as the size and weight of the part increases, and with metals that are readily formed by other processes.

The process, like other processes, has its limitations. A part being considered for investment casting should be designed to take full advantage of the good points and overcome, if possible, its limitations.

The Faraday Lecture

THE Institution of Electrical Engineers' Faraday Lecture was presented on February 14th at the Central Hall, Westminster, by Mr. L. J. Davies, Director of Research and Education, the British Thomson-Houston Company, Ltd., Rugby. The theme of the lecture, "Lamps and Lighting: a Record of Industrial Research," was presented by Mr. Davies in popular language, with the help of a large number of striking demonstrations.

After a brief introduction on the fundamental properties of light sources and lighting in relation to vision, Mr. Davies dealt with the different electrical methods of producing light and described incandescent filament lamps, the arc discharge and fluorescent lamps. A graphic experiment served to emphasise the importance of distinguishing between the colour appearance of a lamp and its colour rendering properties. For this purpose a white screen was illuminated first by a tungsten filament lamp behind a yellow filter and then by sodium discharge lamps, the appearance of the screen being unchanged. When, however, the same lamps were used to illuminate a scene containing colour, a striking difference in the colour rendering properties of the apparently similar yellow sources was revealed.

To illustrate some of the diverse applications of lighting, Mr. Davies chose examples from the lighting of mines and streets. He stressed the importance of brightness ratio in street lighting and pointed out that it was not generally appreciated that the greater the difference in brightness the more easily could movement be detected. To demonstrate the speed of visual perception a straight fluorescent lamp with its ends only luminous was moved at right-angles to its length. Then, because of the fact that the eye perceives the motion of brighter sources more quickly than that of less bright sources, the tube appeared to bend during the movement.

Finally, Mr. Davies had something to say about intermittent lighting and the growing importance of this subject to photographers and engineers. He showed how recent advances had been made in the application of electronics to discharge lamps, whereby flashes of very short duration (for example, a few millionths of a second) could be produced. The fact that the flash could be repeated periodically was of considerable importance in the making of experimental observations in science and engineering.

Increased Bulk Supply Charges for Electricity

THE British Electricity Authority has given notice that the cost of electricity to the area electricity boards will be increased from April 1st next. On that date a revised tariff will come into force, which is estimated to increase the overall cost of bulk supplies by approximately 2 per cent, although the effect on individual boards will vary. This increase is exclusive of the effect of the recent rise of 4s. 2d. per ton in the price of coal. The tariff incorporates a fixed charge per kilowatt of maximum demand and a running charge per unit consumed. It will apply on a uniform basis to all area boards, subject only to regional fuel cost adjustments.

The kilowatt demand charge has been raised by 7s. 6d. per kilowatt from £3 15s. to £4 2s. 6d. On the other hand, the running charge of the new tariff has been reduced from 0·335d. to 0·33d. per unit—reflecting economies in operating costs resulting from the new and more efficient plant—and is subject to a coal price adjustment of 0·0007d. per 1d. variation in the price of fuel in the respective areas from a basic figure of 38s. per ton.

The raising of the kilowatt demand charge is made necessary by a change in the basis of assessment, the rising capital charges on new plant and equipment and other increased costs, and the decision of the Authority to build up its statutory central reserve fund out of its own revenues instead of relying only on contributions from the area boards as has been done hitherto.

The change of assessment was foreshadowed in the Authority's annual reports. The chargeable demand will be the simultaneous maximum demand of an area board on the Authority instead of, as formerly, the two years' average of the aggregate maximum demands at all points of supply in the respective areas. As in the case of the tariff for 1950–51, the maximum demand will be measured on working days during the daytime, i.e., between 7 a.m. and 7 p.m. from Monday to Friday and 7 a.m. and noon on Saturday. If the demand so measured is exceeded by the demand at other times, the excess will be charged for at the rate of one-third of the demand charge. This is designed to encourage the development of night and week-end loads to improve the load factor.

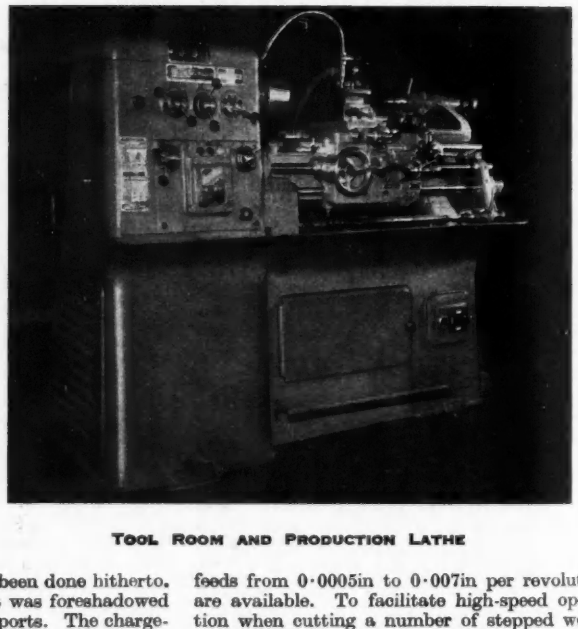
Copying and Tool Room Lathes

AT a recent demonstration arranged by H.E.B. Machine Tools, Ltd., of 79, Portland Place, London, W.1, there were shown in operation two hydraulic copying lathes and a high-speed tool room or production lathe made by H. Ernault-Batignolles, of France.

The tool room lathe, which is designed to swing work 11in diameter over the bed, 7in diameter over the saddle and up to 20in long, is illustrated below. Totally enclosed within the rigid box-form cast base are the 4 h.p. driving motor, switchgear, coolant tank and pump. The main motor drives a pulley in the headstock at a constant speed of 2750 r.p.m. through vee belts. From the pulley power is transmitted through trains of fixed and sliding gears to give a range of twenty spindle speeds from 32 to 2500 r.p.m. This range of speeds, coupled with the rigid construction of the lathe, makes it equally suitable for high-speed production work using carbide tipped tools or normal tool room work. The nickel-chrome steel spindle is mounted on tapered roller bearings and is arranged for use with chucks or collets. All of the gears in the headstock are of nickel-chrome steel with ground teeth, and a built-in lubricating pump maintains a constant flow of oil over them whilst the machine is running.

The feed box drive is transmitted from the headstock through a train of gears on a quadrant plate, and the use of a four-stage selector and a seven-stage Norton train gives twenty-eight pitch ratios for metric or Whitworth threads. When it is required to cut special threads the lead screw drive can be connected directly to the first gear train without passing through the Norton box. The normal screw-cutting range is from 0·25 to 0·35 metric and 8 to 112 threads per inch Whitworth.

The feed shaft is driven through an adjustable friction clutch, which also provides an overload safety device. Twenty-eight sliding feeds from 0·001in to 0·014in per spindle revolution and a similar number of surfacing feeds from 0·0005in to 0·007in per revolution are available. To facilitate high-speed operation when cutting a number of stepped workpieces a seven-position adjustable step turret is fitted on the sliding feed.



TOOL ROOM AND PRODUCTION LATHE

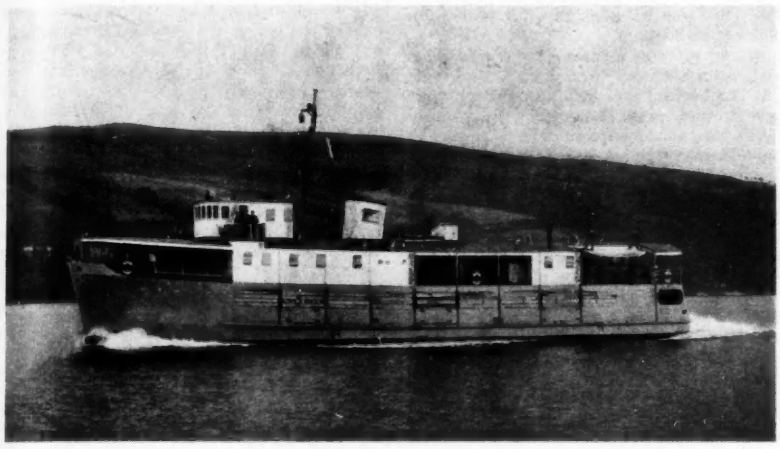
One of this firm's copying lathes was described in THE ENGINEER of December 22, 1950, and at the recent demonstration there was shown a machine of similar design fitted with special attachments for turning patterned moulds and other cylindrical workpieces having contoured surfaces.

On this copying lathe the master piece is held in a chuck or mounted on a mandrel driven through a roller chain or gearing from the headstock chuck, in which the work blank is held. The tracer of the hydraulic copying attachment controlling the movement of the

tool slide is in constant contact with the rotating master. During longitudinal travel of the tool along the blank the tracer moves at the same speed along the master and actuates the saddle to feed the tool in and out of the workpiece to cut a contour similar to that on the pattern. Internal or external patterns can be machined with equal facility and at high production speeds.

Motor Vessels "Orinoco" and "Apure"

THE twin screw, shallow-draught motor vessels "Orinoco" and "Apure," boarded up and fitted with temporary stiffening, are at present proceeding under their own power on passage to Venezuela. They have been constructed by Yarrow and Co., Ltd., to the order of Cia. Anon. Venezolana de Navegacion, Caracas,



M.V. "ORINOCO"

Venezuela. The vessels are destined for the owner's passenger, cargo and cattle service on the upper reaches of the Orinoco River and its tributary the Apure. At certain periods of the year there are stretches of shallow water to be negotiated, so that the service draught was restricted, and to meet this requirement a tunnel screw design was adopted, the tunnels being fitted with the Yarrow automatic hinged flap for maximum propulsive efficiency.

The two ships, which are constructed to Lloyd's classification for river service, have the following particulars :—

Length overall	140ft
Breadth	33ft
Depth to main deck...	6ft 6in
Depth to promenade deck ...	14ft
Load draught	3ft 8in
Deadweight	100 tons
Power...	600 b.h.p.
Speed	20·5km per hour

Accommodation is provided for sixteen first-class passengers in eight two-berth cabins on the promenade deck, and aft on the same deck there is space for twenty-five hammock billets for deck passengers. The dining space, galley, pantries and other passenger amenities are also arranged on this deck. For the carriage of live-stock spaces are arranged forward and aft on the main deck and the ten corrals can hold forty head of cattle.

Navigation on the river called for good steering qualities, and special attention has been paid to the steering arrangements, and triple-geared hand steering gear operates twin balanced rudders to give easy manœuvring.

The propelling machinery consists of two British-Polar diesel engines, each having seven cylinders of 180mm diameter by 300mm stroke, and developing 320 b.h.p. at 500 r.p.m. Heat exchangers are fitted and the circulating pump on the engine circulates the cooling water, while the river water is circulated by an independent electrically driven pump. Two 15kW, 100V d.c. generators are installed and other auxiliaries include a diesel-driven general service pump, an air compressor, and an electrically driven fire and general service pump. The deck machinery includes a diesel-driven anchor windlass and a hand warping capstan.

Founders Company Fellowships

THE Worshipful Company of Founders of the City of London has announced some particulars of Fellowships which it awards to give facilities for advanced education to men who have already completed their normal course of training at a university or other educational institution of a high standard. The company believes that the development and progress of founding and the science of metallurgy must depend very largely on attracting to the industry highly trained men of evident talent. The Founders Company Fellowships, therefore, are available to candidates who appear likely to be able to make good their careers in the founding industry if afforded facilities for further courses of study.

Fellows are chosen by a selection committee from applicants who have been trained in chemistry, physics, metallurgy and allied sciences. In addition, the Company says, some previous practical foundry training and experience, together with, if and when possible, the Diploma of the British Foundry School, would carry weight with the selection committee. At the same time, considerable attention is given to the candidate's character and powers of initiative. Courses to be followed may include research, a period in a certain works, or facilities for gaining foreign experience. In each case, the particular wishes and aptitude of the Fellow will be taken into account. The normal value of a Fellowship is £300 a year, and it will be renewable for a second year and, in special cases, for a third year. One Fellowship is granted each year so that in ordinary circumstances there are two Fellowships in existence. The Fellow will be expected to devote his whole time to work approved by the Founders Company. The tenure of the Fellowships dates from September 1st, and candidates should not be less than twenty-one years of age on September 1st of the year of application.

Applications must be received not later than May 1st by the Clerk of the Worshipful Company of Founders, Founders Hall, 13, St Swithin's Lane, London, E.C.4, to whom all inquiries should be addressed.

Electronics in Naval Architecture: Some Application to Research Problems

A PAPER entitled "Electronics in Naval Architecture: Some Applications to Research Problems," was read before the North-East Coast Institution of Engineers and Shipbuilders on January 26th by Professor L. C. Burrill, M.Sc., Ph.D., and A. G. Boggis, B.Sc., and the main points made by the authors are summarised below.

The application of electronics in industry has steadily increased during the post-war years. In light engineering, operations which were carried out by hydraulic or mechanical means now have electronic control, and this has generally resulted in cheaper and easier production. In the field of research work the displacement of mechanical by electronic devices has meant that items can now be observed and measured which could not be done previously, and the investigation of the performance of high-speed petrol engines is instanced.

The paper discusses the general requirements of instrumentation and a transducer is mentioned as being necessary to convert mechanical displacement into a change in some electrical parameter, usually by a change in voltage. Transducers being of low sensitivity, an amplifier is required to amplify the signal voltage for use with the indicating instrument which measures the changes. Considering the problem of measuring the resonant hull vibrations it is stated that the two-node vertical vibrations of ships' hulls have a frequency range of 60 to 150 vibrations per minute, which is a low value from the point of view of electronics. Because vibration measurement is generally dependent upon the vibration effect in a secondary mass-spring system, the natural frequency of the measuring instrument must lie below that of the ship's hull for measuring displacements, and above it when measuring accelerations. The paper records the fundamental requirements of a mass spring system and the disadvantages of mechanical displacement meters.

Referring to the designing of displacement and resonance meters, the authors state that the usual solution to the problem is to use the inverted pendulum for horizontal vibration and the astatized pendulum for vertical vibration. Some instruments are described and the vibration ranges, damping factors and limitations given. For obtaining a continuous record the acceleration pattern instrument based on simple electronic accelerometers is advocated, which is portable because the transducer is small. Three designs of instruments for converting displacements into voltages are described — using resistance wire strain gauges either bonded or unbonded and using variable inductance. In the paper it is stated that two resistance gauge accelerometers employing bonded and unbonded gauges, having a resistance of 10,000 ohms, have been considered. The unbonded gauge instrument, using a carrier supply of 50 c/s, proved not robust enough for ship work. The second instrument, using bonded gauges, proved successful for measuring ship vibrations and, to cover the range of frequencies, three units were built to give natural frequencies of 10, 20 and 30 c/s, with corresponding response ranges of 350, 700 and 1000 cycles per minute.

Current is supplied from a dry battery and oscillograph amplifiers are cut off below 0·5 c/s, so that only voltages having a frequency above this value are recorded. Damping is obtained by shaping the end masses and filling the instrument with "Silicone" fluid.

Continuing, the paper mentions three methods of amplification, namely, the direct-coupled amplifier, which is rather bulky and suffers from the disadvantage of a drifting zero; the carrier-wave amplifier, which is convenient for obtaining low-frequency response; and the low-frequency compensated amplifiers.

On the subject of laboratory vibration work on entrained water problems a previous paper is referred to, and in connection with the instrumentation the difficulty of maintaining the oscillator at a constant frequency is noted.

Among the applications of resistance strain gauges is their use in measuring the polar moment of inertia of a propeller when swinging in air and in water. Other applications of electronic instruments mentioned are the measuring of small thicknesses and the metacentric height of a ship. The latter instrument is based on a light pendulum mounted so that a photo-cell may be used to measure its deflections. The angle of heel is indicated on a dial or in terms of metacentric height for a given heeling moment at loaded displacement.

The New Tacoma Narrows Bridge, U.S.A.

THE new suspension bridge over the Puget Sound, between the city of Tacoma and the Kitsap Peninsula, in the State of Washington, was opened to traffic last October almost ten years after the failure of its ill-fated predecessor. It was illustrated in our issue of January 5th, 1951 on Plate 2. With regard to the collapse of the first Tacoma Narrows bridge, due to excessive oscillation caused by wind action, it will be recalled that on November 7, 1940, the wind, which had been blowing with increasing velocity during the night, reached a recorded velocity of 42 m.p.h. at about 9 a.m., at which time the bridge developed the most violent vertical motion which had been recorded, moving at the rate of 36 cycles per minute. This mode of motion involved nine half-waves with eight nodal points in the main span. At approximately 10 a.m. on that day the centre span developed a torsional movement with a node at mid-span, the angle of rotation at the quarter-point being at times nearly 45 deg. and the amplitude of the vertical motion of the girder approximately 28ft. As a result of the torsional movement, the centre span of the bridge failed, portions of it dropping into the stream; the side spans then sagged, and the towers were bent shoreward by a maximum deflection of about 24ft. The short existence of the bridge demonstrated the necessity of such a crossing over the Tacoma Narrows—traffic over the bridge was 145 per cent more than it had been over the previous system of ferries.

Various committees were appointed immediately to investigate the bridge failure and to develop the necessary corrective measures which would ensure the safety of a new structure. (Excerpts from the main report on the failure of the bridge were published in THE ENGINEER, Vol. 172, 1941, pages 128–30, 145–46, 162–64, 180–82 and 202–04.)

Experiments were conducted in the wind tunnel of the University of Washington with scale models of thirty suspension bridges, which were subjected to wind intensities of up to the equivalent of 100 m.p.h. Approximately four years were spent in research on this project, and it is said that the resulting structure, as it has now been completed, is the most stable suspension bridge in existence.

There are four major differences between the designs of the old and the new bridges, the second Tacoma Narrows bridge having been built on the piers of its predecessor. The new bridge has a total width, centre to centre of stiffening girders, of 60ft, allowing for four lines of traffic, compared with a width of the old bridge of 39ft, permitting only two lines of traffic. The central suspended span remains unchanged at 2800ft, so that the span-to-width ratio of the bridge has been reduced from 72 to 47, a value the same as that of the Golden Gate bridge at San Francisco. The structural weight of the new bridge is 14,000 tons, compared with 8300 tons for the old span. The stiffening girders of the new bridge are open steel trusses having a depth of 33ft, compared with the solid I beams of only 8ft depth which were used in the design of the former bridge. The resulting stiffness of the trusses is approximately fifty-eight times that of the previous ones. The trusses are believed to be deeper than those used on any other suspension bridge. Finally, in designing the new span a number of precautions were introduced to prevent the occurrence of excessive torsional movement.

Substructure

The bridge, as now constructed, is the third largest suspension bridge in the world. The total length of the structure from end to end of the anchorages is 5979ft. The central suspended span is 2800ft and the two side spans are 1100ft. The two main channel piers were undamaged by the failure of the former superstructure, and a thorough examination indicated that they could be used safely to support a wider and heavier bridge, since they were originally built with deep penetration, the weight of the piers themselves, exclusive of the weight of the superstructure, being 47,000 tons for the westerly pier and 59,000 tons for the easterly pier. Also the cross-sectional dimensions of the piers were generous, as it was necessary to build and sink them in the swift currents in the Narrows, which exceed 8 m.p.h. at the east pier. The piers were also designed to resist the force of collision of a 10,000-ton ship drifting at 8 m.p.h.

The towers of the former bridge had been designed with battered legs, which were 50ft apart at the bottom and 39ft at the top, while the new towers were designed with vertical legs, 60ft apart at the bottom and 60ft apart at the top. Thus it was necessary to remove only the existing tower pedestals, which were above the water line, and construct new pedestals 60ft apart to support the new towers. This change effected a better distribution of load on the piers, compared with the old bridge. In addition, an improvement was made by raising the elevation of the pedestals; they are now 18ft higher than the former ones, taking them out of reach of the spray of salt water in stormy weather, which was causing rusting at the bases of the former towers. This alteration required more than 2500 tons of concrete to be added to the two pedestals, bringing the overall size of each to 32ft by 31ft at the base, tapering gradually to a point 40ft above the low tide level.

The deck of the former bridge was made from hard rock concrete weighing 152 lb per cubic foot, while the deck of the new bridge was made of light-weight concrete weighing 116 lb per cubic foot. Thus the weight per square foot of the new bridge was reduced, with the result that the new superstructure, which carries four traffic lanes instead of two, weighs only approximately 1·6 times as much per lineal foot of bridge as the old structure. The added weight of the present superstructure has increased the foundation pressures by 6 per cent.

Because of the increased horizontal pull of the cables due to the greater weight of the new bridge, it was necessary to increase the weight of the anchorages. The total horizontal pull of the cables on the former anchorage was 28,000,000 lb, while the corresponding pull on the new anchorage is 36,000,000 lb. The corresponding increase in weight was accomplished in the following manner. Approximately 13ft of concrete were removed from the sides of each anchorage by blasting down to the top of the footing block to make room for new anchor bars 60ft apart. These new anchor bars, to which the main cables were attached, were then set in place and embedded in new concrete which extended the width of the old anchorage by 8ft in each direction. In addition, each anchorage was extended at the back by a distance of 20ft, forming a U around the remaining concrete core. Thus about 65 per cent of the old concrete was re-used in the new anchorage. The weight of each of the new anchors is approximately 36,000 tons.

Additional savings in the new structure were made by re-using the major parts of the original west approach. It was found that by substituting light-weight concrete in the deck of this approach in place of the original concrete, the girders of this structure and the tower frames would safely carry two additional traffic lanes. The original value of all parts of the old bridge which were utilised in the design of the new structure, including the two main piers, anchorages and the west approach, was approximately 1,800,000 dollars, which, due to increased construction costs, had a replacement value of from 3,000,000 dollars to 3,500,000 dollars.

Superstructure

The wind tunnel research undertaken in conjunction with the design of the new span showed how turbulent air flow and the small, intermittent, alternating forces which it produces can cause a bridge structure to oscillate when successive forces become resonant with some period of oscillation of the bridge. Methods were developed to nullify these forces or to reduce their effect to such a point that the inherent stability of the structure would be able to dissipate the energy of oscillation.

Each traffic lane was separated from the next one by open steel gratings, which serve as stabilising agents, equalising pressure above and below the deck. They also act as effective dividing strips and tend to keep vehicles in their proper lanes. At the centre of the main span there are heavy diagonal members on either side of the bridge connecting the cable with the top chord of the stiffening truss. These members are double-acting hydraulic jacks, which act as energy-absorbing devices should there be any tendency in the bridge for oscillation to start, and to cause a differential horizontal movement between the cable and the truss. Additional jacks were installed in the towers, connecting the top chord of the main span with the top chords of the side spans. Near the bottom of the towers other jacks were installed to act as a couple with the top chord jacks, bracing being provided below the stiffening truss at each of the piers. It is said to be questionable whether or not these jacks will be utilised to any great extent, but that they give an added safeguard against oscillation in heavy storms. A third precaution, to guard against torsional motion, was the incorporation of a double lateral system of bracing the stiffening trusses. In practically all existing suspension bridges only one system of horizontal bracing is used between the chords of the stiffening girders. In this case, however, horizontal bracing was placed between both the top and bottom chords.

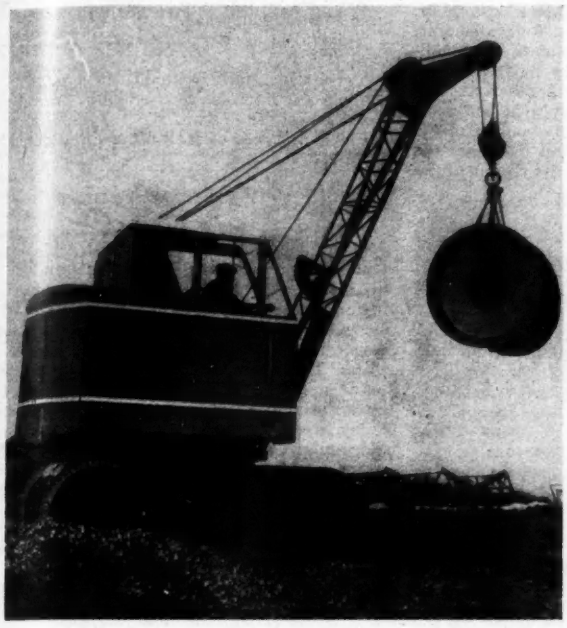
Construction

Prior to pouring the concrete road slab of the bridge, plywood deck moulds were installed along the entire length of the span. Initial pours were made in the two outside lanes, 480ft shoreward from each of the two main towers. The concrete was poured from lorries travelling on a 12ft wide timber service roadway. The next stage was the pouring of the outside lanes over a distance of 250ft on either side of the bridge centre. Successive pours then completed the placing of concrete for the outside lanes, and the construction of the central road slab then proceeded in a similar manner. Concrete was poured to a depth of 5½in, and a wearing surface ½in thick was then added. The reconstruction of the bridge took twenty-nine months, and the cost of the structure was about 13,600,000 dollars. The design of the bridge was by the Washington Toll Bridge Authority, under the direction of Mr. Chas. E. Andrew, chief consulting engineer. The structural steelwork was fabricated and erected by the Bethlehem Pacific Coast Steel Corporation, and the concrete contractor was Woodworth and Co., of Tacoma, Washington.

INGERSOLL-RAND WORKS EXTENSION.—A contract has been placed for a large extension to the Trafford Park, Manchester, works of Ingersoll-Rand Company, Ltd. These works were opened in 1933, but during post-war years the entire layout of the works has been changed and a large amount of modern machine tool equipment installed. An extension was completed in 1949 for the line assembly of portable air compressors and plant is now being introduced to provide large-scale production of "Carset Jackbits." With the new extension, which it is hoped will be completed in July, not only will production be increased but it will be possible to introduce other products into the production programme.

A Six-Ton Mobile Crane

WE recently attended a demonstration of a new 6-ton full-circle-slewing mobile crane, now being made by K. and L. Steelfounders and Engineers, Ltd., of Letchworth, Herts. This crane, illustrated above, is the latest addition to the "Jones" range of machines and it is known as the "KL66." When it is fitted with a 20ft swan-neck or a 25ft channel jib the crane is capable of handling loads from 2 tons at 18½ft radius to 6 tons at 9ft radius. Jibs of lattice construction up to 60ft long can be fitted for handling lighter loads at greater radii. Each of its four motions, hoisting, slewing, travelling and derricking, is independently operated and is reversible.



SIX-TON MOBILE CRANE

The crane is driven by a Perkins 37 h.p. oil engine and all its movements are controlled mechanically. The engine is fitted with a maximum speed governor and its speed is controlled through the driver's accelerator pedal during crane operation. Power is transmitted to each motion through an individual gearbox and the movements are controlled through dry-plate clutches. Brakes fitted on the hoisting and derricking gears are arranged for semi-automatic operation and a self-locking sprag brake is provided on the slewing gear for locking the superstructure of the crane when travelling. All the clutches and brakes are readily accessible for adjustment and maintenance purposes.

The crane's maximum load of 6 tons can be hoisted at speeds up to 40ft per minute and lighter loads up to 2 tons can be raised at 120ft per minute. The hoisting gear is operated through a joy-stick lever, which gives very sensitive control to enable small inching movements both when raising or lowering loads. The crane slews on a large ring of live rollers at speeds up to 2½ r.p.m. in each direction and slewing and hoisting can be carried out simultaneously if required. The derricking gear, which is completely independent of the other motions of the crane, will raise the jib from maximum to minimum radius in twenty seconds. This motion can be effected under load and the time rating is designed to allow it to be operated at every crane cycle without overheating.

When travelling, all four wheels of the crane are driven through a large plate clutch, a three-speed gearbox and a centrally disposed differential gear. Power is transmitted to the axles from the differential through heavy roller chains. With a full load of 6 tons the crane can be driven at 1·5 m.p.h. in low or 3 m.p.h. in second gear. On level ground the travelling speed in top gear is 6 m.p.h. and gradients up to 1 in 8 can be negotiated by the machine when it is travelling light. All four wheels are fitted with two-leading shoe-type Girling brakes and the pneumatic tyres are fitted with restrictor wheels. These restrictor wheels, in addition to limiting deflection of the tyres when slewing the crane, serve to provide additional bearing area when the crane is working over soft ground. The crane has a turning circle of 46ft diameter and steering is through a large-diameter wheel set at the optimum angle for easy manipulation. When the superstructure is slewed to the rear of the crane steering is automatically reversed to normal action.

The makers point out that if required the crane can be fitted on a crawler chassis and it can also be mounted on a lorry or a railway chassis. The wide range of optional equipment available with the crane includes an air-compressor for inflation of tyres by engine power; special equipment for working with single or double-chain grabs; electric lighting equipment; an automatic safe load indicator; a magnet equipment including a self-contained generator and all ancillaries, and a tropical cab for hot climates.

When fitted with a standard 20ft jib the crane weighs about 13½ tons in full working order and, when mounted on a wheeled chassis, the maximum weight on any one wheel with the crane fully loaded is 9·7 tons.

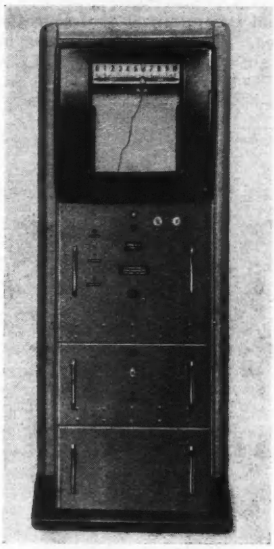
An Oxygen Analyser

OUR illustration shows the outward appearance of a commercial form of oxygen analyser made by Elliott Brothers (London), Ltd., Lewisham, London, S.E.13. It is intended to give a continuous indication and chart record of the oxygen content of a gas and it can be used with a controller for maintaining the oxygen content constant at a given value. The analyser, which operates by virtue of the paramagnetic properties of oxygen, is the result of work carried out by the research and development department of the Distillers Company, Ltd., by arrangement with whom the new DCL-Elliott is now being manufactured commercially.

The basic principle of the analyser was demonstrated nearly 100 years ago by Michael Faraday, who showed that, when a glass test-piece of dumb-bell shape was suspended by a silk fibre in an inhomogeneous magnetic field, the position assumed by the test-piece depended on the amount of oxygen in the surrounding gas. Movement of the dumb-bell was indicated by a pointer of fine straw. Later experimenters, using a glass dumb-bell suspended between the poles of a permanent magnet and with a light beam as a pointer, developed an instrument for indicating the oxygen content of a gas.

In the Elliott instrument a quartz dumb-bell carrying a small mirror is attached by a suspension strip to an adjustable torsion head. The dumb-bell and mirror are mounted between specially shaped pole-pieces of a powerful permanent magnet in a cell, which is designed to produce an effective sweep-out time of from eight to twelve seconds without disturbing the dumb-bell. The gas detector assembly is thermally insulated and thermostatically controlled, to eliminate ambient temperature errors.

Movement of the dumb-bell is detected by a light beam, twin photocells and a d.c. amplifier of special design, which operates an "Elliottronic" continuous chart recorder, for example. The instrument is calibrated directly in percentage oxygen and may be supplied in various ranges from 2 per cent to 100 per cent oxygen for full scale deflection. The accuracy is stated to be ±1 per cent to ± 2 per cent of full scale deflection, according to the range of the instrument. Since the volume of the gas sample passing through the cell is very small the design of the sampling system is such that a relatively large volume of gas is continuously passed through the apparatus, only a small proportion being admitted to the cell. In this way undue time lags are avoided. The sampling system includes a suitable filter and pressure regulation arrangements with a visible bubbling chamber. A fan aspirator is fitted for obtaining the sample and introducing the reference gas for automatic standardisation.



OXYGEN ANALYSER

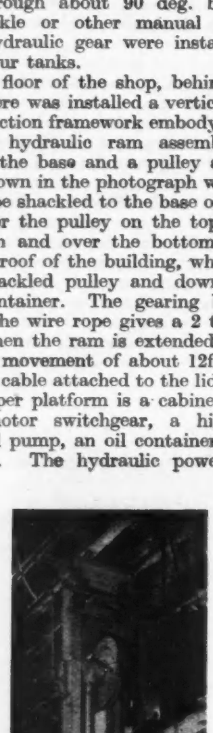
Provision is made for periodic checking of the zero by passing a non-paramagnetic gas through the cell. Nitrogen may be used for this purpose; alternatively the sample can be washed through chromous chloride. Correction for changes of barometric pressure is effected automatically at intervals of 30 minutes by standardising the apparatus on a mixture of known composition—air, for convenience. The instrument is particularly suitable for the estimation of mixtures of oxygen in hydrocarbon gases, combustion products, &c. It is stated that the only gases which interfere with the calibration are nitric oxide, nitrogen peroxide and chlorine dioxide. These gases also possess paramagnetic susceptibility.

The analyser is self-contained and fitted in a metal cabinet, as illustrated. It is also available as an indicating instrument and as a recorder-controller incorporating the "Elliottrol Trimode" unit. Operation is from 200V to 250V single-phase supply.

Hydraulic Lifting Equipment

PARTICULARS of a recent new application of its hydraulic handling equipment have been sent us by Bromilow and Edwards, Ltd., of Foundry Street, Bolton, Lancs. The hydraulic gear in question was installed for raising the covers of large transformer impregnating tanks at the works of Metropolitan-Vickers Electrical Company, Ltd. The hinged covers of these containers are some 15ft diameter and weigh from 3 to 5 tons. Prior to the installation of hydraulic gear the covers were raised through about 90 deg. by means of block tackle or other manual gear. Four sets of hydraulic gear were installed, one for each of four tanks.

On the floor of the shop, behind each container, there was installed a vertical stanchion, channel-section framework embodying a double telescopic hydraulic ram assembly, with a pulley at the base and a pulley at the upper end, as shown in the photograph we reproduce. A wire rope shackled to the base of the column passes over the pulley on the top end of the ram, down and over the bottom pulley and up to the roof of the building, where it passes over a shackled pulley and down to the lid of the container. The gearing between the ram and the wire rope gives a 2 to 1 step-up, so that when the ram is extended 6ft there is an actual movement of about 12ft at the free end of the cable attached to the lid. Mounted on the upper platform is a cabinet containing electric motor switchgear, a high pressure plunger oil pump, an oil container and a control valve. The hydraulic power circuit is



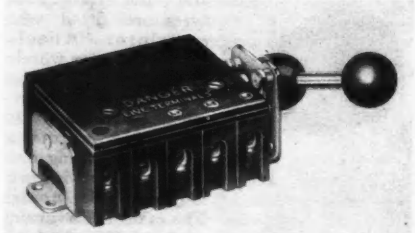
RAM ASSEMBLY IN EXTENDED POSITION

piped up to the lower end of the hydraulic ram assembly and the operator standing on the platform can see that everyone is clear of the container lid before starting up the equipment for the hydraulic ram to open the lid.

When a transformer has been placed in the container a wheel valve is opened in the hydraulic system and the oil is by-passed into the oil reservoir. The ram telescopes into its outer cylinder and the lid is thereby lowered on the container. Fitted at the top of the structure carrying the ram head is a trip gear and once the ram has been extended fully it cannot be accidentally dropped by opening the lowering valve in the hydraulic circuit until the trip lever is operated from the controller's position on the platform.

An A.C. Isolator

THE accompanying illustration shows a 500V, 50A a.c. isolator, designed and produced by J. A. Crabtree and Co., Ltd., Walsall, Staffs, for use with any of the company's motor starters and control panels. It is a self-contained and heavily insulated assembly, and is normally supplied as a four-pole unit, although three and five-pole units are available. The fourth pole breaks first and load interruption is made by the contactor. For circuits where a separate supply is necessary for the operating coil, the five-pole isolator gives complete isolation. In all instances the isolator is capable of opening the circuit under



FIVE-POLE A.C. ISOLATOR

load conditions at its rated capacity. The isolator is held in position by the bearing of the switch-arm, which passes through the side of the housing and by two screws which fix the rust-proofed steel cradle to the back of the housing. This steel cradle accommodates the spring mechanism of the switch-arm assembly and, as can be seen from our illustration, forms a base, to which the individual single-pole moulded switch-bases are fixed.

Where the isolator is used with a contactor, the left-hand cam, which is of a different form from the other four, breaks the operating coil circuit first and thus automatically ensures that the supply is broken by the contactor. This action takes place before the switch-arm of the isolator has completed its movement, which makes for double protection, since the coil circuit is not completed until the isolator is switched fully on, even if the "start" button of the contactor be inadvertently depressed while the control gear is undergoing examination.

The wiring terminals are of a heavy clamping design. Each switch base is completely isolated from its neighbour; all live metal parts are deeply recessed and a moulded plate, fixed by two captive screws, covers the cavities in the switch bases. The live side of the isolator is clearly indicated on this cover. To make the isolator widely adaptable it can be supplied for left or right-hand operation.

THE COAL UTILISATION JOINT COUNCIL.—With the approval of the Ministry of Fuel and Power and the support of the National Coal Board and all branches of the coal and appliance industries, the Coal Utilisation Joint Council has recently decided upon a policy of expansion of its work of encouraging the intelligent use of solid fuel in the wide range of modern appliances now available. This expansion involves setting up regional organisations in eleven regional centres, the development of national and local publicity towards the better use of solid fuel in the home, and the establishment in all the principal towns of the country of an approved panel of solid fuel appliance distributors from whom the public can secure the best possible technical advice and service. Ultimately a comparable advice service on the use of solid fuel will be available from coal merchants, who, already, both individually and through their associations, are closely linked with the work of the Council. The expansion of the headquarters' staff has included the appointment of Mr. Eric Bellingham, O.B.E., LL.B., as Director General.

Rock-Fill Dams*

By L. F. HARZA

THE three fundamental requirements of a rock-fill dam are an ample spillway to prevent overtopping, a water-seal diaphragm, and stable slopes. The first requirement is obvious and is common to all dams and need not be considered here.

The types of dams as distinguished by the locations of the water-seal elements can be classified as follows:—

Type (*a*) on the back or water surface of the dam, "water-slope seal."

Type (*b*) internally and centrally located thin core.

Type (*c*) centrally located thick core.

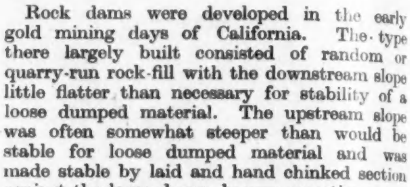
Type (*d*) internal core sloping toward the back or heel of the dam.

The four types of rock-fill are illustrated by Figs. 1, 2, 3 and 4.

WATER-SLOPE SEAL

Rock dams were developed in the early gold mining days of California. The type there largely built consisted of random or quarry-run rock-fill with the downstream slope little flatter than necessary for stability of a loose dumped material. The upstream slope was often somewhat steeper than would be stable for loose dumped material and was made stable by laid and hand chinked section against the loose dump, known sometimes as a "dry masonry wall" from the absence of mortar. In the earliest dams the joints in the water surface of this wall were pointed with mortar to obtain a water seal. Later, reinforced slabs were poured against the dry wall. These slabs were, of course, toed into trenches excavated to sound rock along the bottom and side slopes of the dam sites.

The loose fill was usually "washed" or "sluiced" with a large volume of water throughout the period of dumping in order to effect the maximum possible degree of settlement before placing the concrete slab. But in spite of the best which could be accomplished



A.—Quarry-run random rock.
B.—Laid and chinked stone.
C.—Impervious slab, reinforced concrete or other type

FIG. 1—*Type* (a) *Water Slope Seal*

by presettlement with water during construction and by an interlocking dry wall of large and sometimes squared rock under the slab, and a well-jointed slab of maximum flexibility, a considerable settlement always occurred rapidly in the first years of service and thereafter approached an asymptote and often amounted to some 2 per cent of the height. This was enough, in spite of liberal reinforcement, to crack the slab, usually in diagonal pattern, and to require the placing of asphalt or other sealing material in the cracks. The tendency to crack seems to have had little tendency to confine itself to the artificial jointing system, which might therefore well be omitted in favour of a monolithic slab with all reinforcing steel passing through the construction joints as first done on the McKay dam (of gravel) in Oregon.

In some regions, as in North Africa, flexible types of slabs using plastic material have been developed to improve upon the somewhat brittle characteristics of a concrete slab, but the author is not familiar with the degree of success thus achieved.

It is doubtful if any material has proven so entirely satisfactory as not to require inspection and repair, caulking or pointing of cracks at intervals. This type of dam should be con-

* Fourth Congress on Large Dams, New Delhi, 1951. Paper R.20 (Question No. 13), U.S.A. Abstracts.

sidered satisfactory only for storage reservoirs which are regularly drained at intervals in connection with the use of the stored water and where access to the water-seal diaphragm for maintenance purposes therefore becomes possible without waste of water or head. They cannot be considered satisfactory for hydro-power dams where a full, or partially full, reservoir is depended upon at all times to maintain a power head and where exposure of the slab for maintenance is therefore never possible.

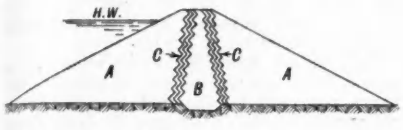
At least one dam, the El Vado, in New Mexico, was provided with a plate steel diaphragm on the water slope intended to accommodate itself to settlement and temperature changes without injury to its watertight integrity. The result has not been reported.

The advantages of the water-slope seal are that the entire volume of the dam contributes to the strength against shear or sliding; construction of the fill and the water seal become two separate and largely independent operations in that the fill can progress far ahead of the seal, thus giving time for considerable settlement before starting the latter; and the fill is built as a single unit.

Central Core Dams

In at least one dam a central core was built of steel plate, the Lower Otay dam in California, but this dam was destroyed by overtopping, before its degree of permanence was proven by service.

Vertical concrete core walls have also been built, but are subject to almost certain serious cracking resulting from unequal loading. To



A.—Random rock-fill.
B.—Rolled core.
C.—Filters, serrated contact surfaces unavoidable.

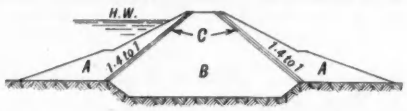
Fig. 2—*Type* (b) *Vertical Earth Core*

seal such cracks a core of earth has sometimes been placed ahead of the concrete core. Any thin central core necessitates a very rigid construction programme, to maintain equal elevation and equal compaction of the fill on each side of the core at all times during construction, to minimise distortion and serious cracking from unequal loading. It also tends to divide the rock-fill into two distinct parts, one on each side of the core, a more expensve operation often requiring two sources of rock for convenient operation; moreover, only the section of rock downstream from the core assumes the support of the water load.

A core of earth rather than concrete is the more typical, frequent and preferred type in the United States. It requires a graded filter between earth and rock to prevent rain, waves and drawdown from ravelling out or disintegrating the earth into the pores of the rock on the upstream side and to take care of rain, combined with the disintegrating effect of escaping seepage on the downstream side of the core. Since earth is usually cheaper to load and handle and roll than rock, requiring no drilling nor blasting, the central earth section is usually as thick as available earth material will permit without increasing external slopes and may vary anywhere from a relatively thin wall to a dam largely of earth. However, there are certain features, both as to methods of construction and to method of functioning, which clearly segregate the earth centre dams into two types: type (*b*), those where the slope of the contact between earth and rock is steeper than the angle of repose of the earth, and type (*c*) those where this contact slope is equal to or flatter than the angle of repose of the earth, which we might describe respectively as the earth core rock-fill dam, type (*b*), and the rock-supported earth-fill dam, type (*c*).

In the former, the central earth section forms a true "core" whose chief function is imperviousness. The core, the two filters and the two rock-fills upstream and downstream of the core must all be built as nearly simultaneously as possible. This is a very exacting and often costly requirement which is never quite possible and results in a rough serrated contact between earth centre and filters, between individual filter layers and between filters and rock. Filter layers must therefore be designed in thin serrated layers on the exposed slope of each lift of core or rock material, these slopes to be individually stable between changes in slope (Fig. 2) or, preferably, can be ample in thickness, often 10ft to 25ft, to encompass the maximum limits of irregularity of undesigned rough contact surfaces (not shown). Since filter material is usually screened, this tends to increase the cost.

Where sufficient suitable earth material is available so that the slopes of the central earth



Core slope equal to or flatter than angle of repose of rolled earth core.
A, random rock-fill; *B*, rolled earth core with stable slopes, about 1 on 1·4; *C*, filters.

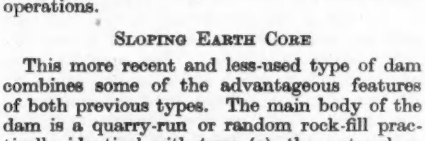
Fig. 3—*Type* (c) *Rock-Supported Earth Fill*

section may be equal to, or flatter than, temporarily stable repose slopes such as about 1·4 horizontal to 1 vertical, then the dam may be considered as of an entirely distinct type. The earth centre will generally be cheaper than equivalent section of rock and may be built as an independent operation reasonably ahead of, instead of simultaneously with, the filters and rock-fills if convenience and weather so dictate; the filter layers may each be only as thick as can be spread conveniently with assurance of maintaining the integrity of each layer, such perhaps as 2ft each, and may often be an unscreened natural gravel if a suitably graded material is available, and perhaps only one layer, and may each be spread on the finished slope of earth as an independent operation; the rock placing may follow the filters and serves the purpose only of weight and shear strength to permit steeper outside slopes of the finished structure and, therefore, less total volume than would be feasible for an all-earth dam.

This latter, type (*c*), or rock-supported earth fill, is usually more economical to build than the earth core rock-fill, type (*b*), if sufficient earth material is available, and is much better adapted to efficient organisation of construction operations.

Sloping Earth Core

This more recent and less-used type of dam combines some of the advantageous features of both previous types. The main body of the dam is a quarry-run or random rock-fill practically identical with type (*a*), the water-slope



A, random rock-fill; *B*, rolled earth core with stable upstream slope about 1 on 1·4; *C*, filters.

Fig. 4—*Type* (d) *Sloping Earth Core*

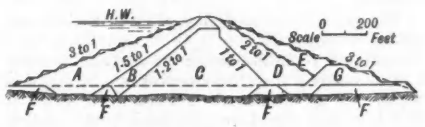
sealed type, with stable rock slopes both fore and aft, and wetted down as much as possible during placing to reduce subsequent settlement. The difference is that it receives an earth blanket instead of a concrete or other impervious diaphragm on the water slope, and then, above this, a rock blanket to support the earth blanket which is steeper than allowable for an independent earth slope. It also requires a filter both above and especially underneath the earth blanket.

A sloping earth core was built at San Gabriel No. 1 dam, Fig. 5, by the Los Angeles Flood Control District in 1933–37. But this was laid on a weathered rock which was too weak to support the load in its natural state and was therefore crushed in place by a heavy sheepsfoot roller to a state which made an underneath filter unnecessary. The first application of a sloping earth core to a conventional quarry run or random rock-fill of the typical type (*d*) was by J. P. Growdon, of the Aluminium Company of America at Nantahala (Fig. 6), in which the typical upper and lower filters are shown. The reason for the contorted core section near the top is not evident.

It has the advantages that it can be built where earth core material is scarce, as in the case of type (*b*); that the sloping core is more flexible than a concrete slab, as in type (*a*), under limited settlement when well protected by a lower filter; that the body of the rock-fill can be built as rapidly and as independently of other operations as desirable; the filter layers, earth layer and upper rock layer, all being laid on stable slopes, can follow in such independent sequence as convenience of operations, seasons of the year, &c., may dictate, as in the case of type (*c*).

The downstream slope of the finished dam is determined by the requirement of permanent stability for the local region with due consideration of the possibility of earthquake disturbance. The upstream slope of the main body of the dam need be only a temporarily stable loose rock slope, neglecting earthquakes, such as 1·4 horizontal to 1 vertical.

Upon this slope the two or more filter layers can be spread without sloughing, provided no earthquake occurs during construction. If it were not for the need of adjustment of filter layers to possible settlement, and assuming that the sizing is so designed that the material



A, quarry-run rock, coarse material upstream, fines downstream; *B*, clayey sand; *C*, quarry-run rock compacted by rolling and tamping; *D*, quarry-run rock, coarse material downstream; *E*, large rock; *F*, existing rock-fill in river bed; *G*, rock excavated from river bed.

Fig. 5 *San Gabriel Dam No.1*

of one layer cannot pass through the pores of the layer beneath, the filter layers would need to be only of minimum thickness to ensure continuity, perhaps 2ft each.

But since settlement is inevitable and sagging of the slope profile would tend to stretch and thus open up cracks in the lower filter, it has been made of a liberal thickness to permit self-healing of each layer in case of expansion in length. Thus, the filter layers under the sloping earth blanket at Nantahala are respectively 14·75ft, 6·5ft and 6·5ft thick from the bottom layer, resting upon the rock, upward.

The earth blanket can be placed and rolled upon this filter, following the spreading of the filter layers as closely or as far behind as may be convenient, which is likewise true of the filter layers on top of the earth blanket. It is this feature which makes this type of dam more convenient and cheaper to build per unit volume than a vertical thin core of comparable volume, and in these respects it shares the same conveniences of construction with type (*c*). However, type (*c*) need not have the thick filter layers of type (*d*).

Since the water pressure and seepage tends to compact the upper surface and to disintegrate the lower surface of the earth blanket, the filter on top of the earth blanket is much less exacting to design and build than the filter underneath. Its purpose is to protect the upper surface of the earth blanket from rain, wave erosion and drawdown.

This is the identical purpose of the gravel blanket or filter underneath the riprap wave protection of any earth dam. But the requirement of types (*c*) or (*d*) is less exacting because of the greater thickness of the superimposed rock which would minimise the erosive power of waves. It could, in fact, be of natural unscreened gravel if a suitably graded material were to be found. The great thickness of the upper filter at Nantahala may be for self-healing purposes in anticipation of humping

of the dam surface as the result of settlement of the rock-fill. This would not be necessary in type (*c*).

Slopes

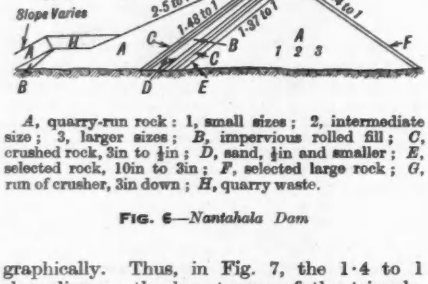
By way of comparison it should be noted that types (*a*) and (*d*) have in common the feature that the rock-fill supports a sloping diaphragm which is subjected to normal water pressure. It is therefore important that every precaution be taken to presettle this rock-fill before the impervious diaphragm is constructed.

On the contrary, to some extent in types (*b*) and, especially, in (*c*), the rock merely provides weight and shear strength. Settlement after construction would merely require adding more rock at the top and would not be otherwise injurious. A poorer grade of rock would be suitable with relatively little effort to presettle during construction. The rock in type (*c*) assists the stability of the earth slopes and permits steeper outside slopes than possible with a purely earth section.

The analysis of stability for types (*b*) and (*c*) would appear to follow in general similar slip circle technique as in a homogeneous material. In type (*d*) the slip line (or circle) on the upstream side, as well as in type (*c*), both upstream and downstream, would follow within the earth, except at or near the bottom of the slope, and a rock berm near the bottom for horizontal resistance might appear to be indicated, as well perhaps as a flattening of the slope below the berm as shown, all dependent upon the characteristics of the earth material.

The problem of stability of loose rock slopes under earthquake forces is a very important feature of rock-fill design in certain regions. Let us assume that the steepest, static angle of repose of an undisturbed loose rock slope is 1·4 horizontal to 1 vertical or a bottom angle of 35°–33′. Then, for example, with a retreating horizontal acceleration of 0·1 *g*, each rock in the slope would in effect have the direction of its effective gravitational pull deflected from the vertical to an angle whose tangent is 0·1 or 5°–43′ from the vertical. To ensure an equal degree of stability of the slope at that moment, the slope angle would need to be flattened by this amount or from 35°–33′ to 29°–50′. This is equivalent to a slope of 1·74 horizontal to 1 vertical. If the horizontal acceleration were 0·2 *g* the slope angle would need to be 11°–19′ less or 24°–14′, equivalent to a slope of 2·22 horizontal to 1 vertical.

Any combination of horizontal and vertical acceleration can, however, best be solved



A, quarry-run rock: 1, small sizes; 2, intermediate size; 3, larger sizes; *B*, impervious rolled fill; *C*, crushed rock, 3in to ¼in; *D*, sand, ¼in and smaller; *E*, selected rock, 10in to 3in; *F*, selected large rock; *G*, run of crusher, 3in down; *H*, quarry waste.

Fig. 6—*Nantahala Dam*

graphically. Thus, in Fig. 7, the 1·4 to 1 slope line on the hypotenuse of the triangle, as the assumed steepest stable static slope line, could be used as equivalent to the direction of gravity. The triangle of forces would then be erected upon this hypotenuse. Thus, for example, if only horizontal acceleration of the particle is assumed, as represented by *bg*, then line *AB* would be the new slope of stability equivalent to 1·4 to 1 for static conditions. If simultaneously there were to be a downward acceleration of *cg*, then line *AC* would represent the slope of stability equivalent to 1·4 to 1 for static conditions. Likewise, if there were to be an upward, instead of a downward acceleration of *cg* then line *AC′* would be equivalent to 1·4 to 1.

The exact significance of these figures and of this method, however, is doubtful. The accelerations considered are momentary and are followed by rapid reversal or other change in direction. Since any actual movement of rock pieces on a slope is a function of time, a momentary unstable condition followed by a reversal causing forces contributing excess stability might not cause any movement. It is a known fact, however, that landslides usually accompany earthquakes and indicate that rapidly changing or reversing accelerations do not necessarily compensate. The facts might be roughly determined by model tests on a shaking table simulating actual earthquake movements, but will involve much uncertainty until data accumulate confirming the behaviour of actual known talus or other natural or artificial slopes under known conditions. It would seem that a seismograph would be a

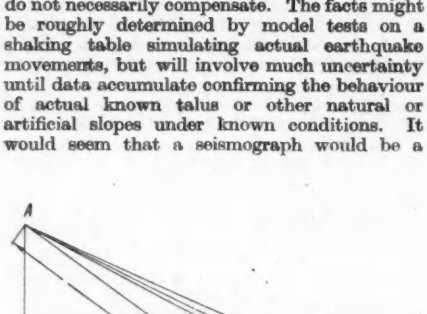


Fig. 7

justified investment at the sites of major loose rock dams.

The only experience which has come to the writer's attention is that of the Cogoti dam in Chile. This dam is a rock-fill dam 277ft high, having a crest length of 525ft. The upstream slope is 1 vertical to 1·5 horizontal, and the downstream slope is 1 vertical to 1·6 horizontal. The water seal is formed by reinforced concrete slabs placed on the upstream slope. On April 7, 1943, a severe earthquake, about VII to IX on the Rossi-Forel scale, occurred at this dam. The following partial free translation is taken from a letter describing the effect of the earthquake on the dam, written by the manager of the department which built the dam :—

"The earthquake of April 7, 1943, reached an intensity in certain parts of the 9th point on the scale of 12. As a result the settlement practically reached the final limit. In spite of the violence of the earthquake, the damages resulting in the structure of the fill were practically of no significance. The concrete slabs remained intact, which is further confirmed by the fact that the leakage remained practically unchanged. Only on the downstream slope of the dam a few slides of rock ran down, but without indicating any danger whatever to the stability of the fill."

The settlements caused by the earthquake, mentioned in the above quotation, were about 0·4m (15in). The settlement from the completion in 1938 to March, 1943 (just before the earthquake), were about 0·35m (13¾in), and since the earthquake, April, 1943, to December, 1946, were only about 0·03m (1¼in). The total settlement since completion in 1938 has been a little less than 0·8m (31in), or about 1 per cent of the total height. Apparently the earthquake merely anticipated the ultimate settlement, as evidenced by the fact that the settlement since 1943 has been almost nothing. The leakage through the dam since 1940 has ranged between 14·8 and 19·4 cusecs. This is excessive and probably reflects the difficulty, if not impossibility, of a concrete slab without cracks. Although earthquake accelerations are not reported, it is probable that they reached at least 0·2 *g* in a quake of the indicated intensity, which, by the analysis previously given, would have required a much flatter slope than 1 vertical on 1·6 horizontal. Perhaps a slope of 1 vertical on 1·7 horizontal might be tentatively considered as sufficiently stable under almost any earthquake conditions based upon the Cogoti experience.

French Engineering News

(From our French Correspondent)

Engineering work on a large scale is to be undertaken in Morocco to establish American air bases. Work will be carried out at Casablanca, Port-Lyautey, Meknes, Agadir and Marrakesh. The first part of the programme will cost about £10 million and about 17,000 workers will be employed under the direction of some 2500 American technicians.

* * *

The port of Abidjan, on the Ivory Coast, was inaugurated recently. The new port will be capable of handling 850,000 tons of shipping each year. It has 1000m of quays and five dockside sheds. A marshalling yard with fifteen tracks has also been constructed and there is a quay 150m long for barges.

* * *

December, 1950, was a good month for the automobile industry. 23,942 private cars were produced (the monthly average for 1950, was 21,441) and a total of 35,657 vehicles were built (average 29,799). In the course of 1950 the industry produced 357,454 vehicles, compared with 285,641 in 1949. Further progress is expected this year and it is hoped that production will increase to 400,000 or 450,000 vehicles annually. This progress, however, will depend largely on the international situation and the supply of raw materials.

* * *

The Chantiers de Provence has constructed two cargo vessels, the "Atlas" and the "Sahara." These 2600-ton ships have overall dimensions of 96·45m by 14m by 8·52m and are each powered by a diesel engine developing 3000 b.h.p. at 150 r.p.m.

The "Ville de Marseille," which will come into service next spring on the Bordeaux-Casablanca run, will be the first packet brought into service by the Compagnie Générale Transatlantique since the liberation. She is now being completed at the Forges et Chantiers de la Méditerranée and will carry 862 passengers. At a speed of 21 knots, fuel consumption will amount to 180kg to 190kg per mile, which is a reduction of about 25 per cent compared with previous vessels of similar design. This economy is effected by the use of high pressure steam turbines and improved boiler design. Auxiliary diesel-driven alternators will generate power in port when the main machinery is shut down. The new propulsion unit is considerably less cumbersome than, for example, that on the Ville d'Alger, where four boilers were needed, compared with three on the new ship. Of these, three one can normally be kept in reserve. An innovation is the fitting of Grinell sprinkler fire extinguishers, used for the first time in French construction. The "Ville de Marseille" has a length of 142m, a breadth of 19m 45, a speed of 21 knots, a deadweight of 2500 tons, and a displacement of 8662 tons.

* * *

An increase in the price of imported coke and coal and a 10 per cent increase in the price of French coal is likely to send steel prices up between 6 or 7 per cent. Taking into account the raised prices of coal, iron ore, scrap and transport, which have taken place since last Autumn, a conservative estimate indicates that steel prices might finally increase by about 15 per cent.

In 1950 French production of pig iron amounted to 7,770,000 tons. Steel ingot production was 8,654,000 tons, and the production of rolled steel was 5,957,000 tons.

With the Saar production, total steel ingot production in 1950 was about 10,650,000 tons and rolled steel production was 7,310,000 tons.

The slight drop in production seems to be due to difficulties in obtaining enough coke and scrap. But for the first time in 1950 monthly production was raised above the 1929 level, which is considered the peak year for French steel production. Steel circles believe the record, reached in October, could have been higher if factories had not been held up by material shortages, but they also express fears for 1951 production unless these supplies are rapidly improved.

Industrial and Labour Notes

Railway Wages

On Friday evening last it was announced that the wage negotiations between the Railway Executive and the three railway unions has ended and that a settlement had been reached. The negotiations had been reopened at the beginning of the week, following rejection by the unions of the recommendations made by a Court of Inquiry, set up by the Minister of Labour, to examine wage claims put forward by the unions, but refused towards the end of last year by the Railway Executive.

The three unions, the National Union of Railwaymen, the Associated Society of Locomotive Engineers and Firemen, and the Railway Clerks' Association, had asked for wage increases of 10 per cent, 15 per cent and 7½ per cent respectively. In stating its inability to meet the demands, the Railway Executive had offered certain wage increases, by which the lower paid grades would have benefited, but made them conditional upon acceptance by the unions of changes in working arrangements which were designed to effect economies and increase railway efficiency. That offer was refused by the unions, and the Court of Inquiry began its investigation.

The Court's report, published a fortnight ago, advocated wage increases of approximately 5 per cent, and recommended also changes in working arrangements very similar to those already suggested by the Railway Executive. The three unions strongly disagreed with the findings of the Court, and shortly after the publication of its report several railway centres throughout the country were affected by decisions on the part of a number of railwaymen to "work to rule," and to stage token strikes—action which the unions failed to stop, despite appeals from the Minister of Labour that no step should be taken which would prejudice the negotiations which he invited the two sides to resume.

The negotiations were reopened at the beginning of last week, but on Wednesday evening the Railway Executive announced that, despite every effort to find a solution, it had not been possible to reach agreement with the three unions. By accepting the Court of Inquiry's recommendations, about £7,000,000 a year would have been added to railway wages, an amount which the Executive offered to increase by a further £2,250,000, making £9,250,000 in all. The Executive also restated its proposals on working conditions. On Thursday of last week, the Minister of Labour discussed the situation with the Railway Executive and also with representatives of the unions, and, amidst increasing signs of more serious strike action, further talks proceeded throughout Thursday and Friday. They resulted in the acceptance by the unions of an offer made by the Railway Executive of wage increases totalling in the aggregate about £12,000,000 a year. The increase, which is retrospective to January 1st, represents a rise of about 7½ per cent in the wages of all grades. The Executive stated that to meet the cost it would become necessary to obtain authority to increase railway fares, rates and charges. The union representatives acknowledged the need to co-operate fully with the Executive to increase efficiency and improve productivity in the railway industry, and undertook to examine forthwith any proposals to that end which the Executive put forward.

Iron and Steel Prices

The Iron and Steel Prices Order, 1951 (S.I. No. 252), which has been made by the Minister of Supply, came into operation on February 21st. By it the maximum prices of iron and steel have been increased, mainly, it is stated, as the result of the recent addition to the price of coal and coke.

Some examples of the price alterations per ton are as follows, the old prices being shown in parentheses: basic pig iron, £10 19s. (£10 11s. 6d.); forging ingots, £18 2s. 6d. (£17 16s.); billets (soft basic), £17 4s. (£16 16s. 6d.); billets (acid), £22 11s. 6d. (£22 4s.); tinplate and sheet bars, £17 6s. 6d. (£16 16s. 6d.); wire rods, £21 15s. 3d. (£21 2s. 3d.); plates, £21 3s. (£20 14s. 6d.); joists, £20 1s. 6d. (£19 13s. 6d.); heavy rails, £19 17s. 6d. (£19 2s. 6d.); uncoated sheets, £29 13s. (£28 16s.); re-rolled products, £22 5s. (£21 16s.); cold rolled strip, £33 12s. 6d. (£33); spring steel bars, £24 17s. (£24 8s.); bright steel bars, £31 14s. 3d. (£31 2s. 3d.); wire rope, £72 10s. (£69 15s.); tinplate, per basic box, £2 5s. 2½d. (£2 4s. 4d.); austenitic stainless steel billets, 1s. 3½d. per lb, plus 10 per cent (1s. 3d.).

Changes in Wage Rates

The Ministry of Labour has announced that changes in wage rates reported to have come into operation in the United Kingdom during January resulted in an aggregate increase of about £564,000 in the weekly full-time wages of 1,849,000 workpeople. Among those affected by the increases were workers employed in coal-mining, road passenger transport services, the iron and steel industry, the heavy chemicals manufacturing industry, and electricity supply undertakings.

In the coal-mining industry the national minimum wages were increased in January by 7s. a week for adult underground workers and by 5s. for adult surface workers, shift rates for adult day-wage underground and surface workers being increased by 1s. 2d. and 10d. a shift respectively. In the road passenger transport industry there were increases of from 7s. to 12s. a week for drivers and conductors in the London area, and of 7s. 6d. in other areas; road passenger transport maintenance staffs, receiving increases of 5s. to 6s. 2d. in London and 7s. 6d. or 6s. 6d. in other areas. In the iron and steel industry there were small increases payable under sliding-scale arrangements based on the index of retail prices. The result of the increases in January was to advance the index of rates of wages (June 30, 1947=100) by 1 point. At the end of January the index figure for all workers was 115.

Colliery Overmen's Wages

The National Coal Board has concluded an agreement with the National Association of Colliery Overmen, Deputies and Shotfirers for an increase of the shift rates of deputies by 3s. a shift. Agreement has also been reached upon increases for overmen and shotfirers, the increase for overmen being 22s. 6d. a week, that is on the same basis as deputies of 3s. a shift for seven and a half shifts paid. Shotfirers, who received no increase or an increase of less than sixpence a shift under the wages agreement made last November, are now to have their rates increased by 2s. 10d. or such lesser sum as will, with last November's increase, make up to 2s. 10d. The revised rate is not to exceed a ceiling of 32s. 6d. per shift, including, as formerly, the "skilled shilling" and any other flat rate where payable. The minimum shift rate of shotfirers is to be increased from 24s. to 26s. 4d. a shift.

It was agreed that all these increases should become effective as from the beginning of the first full pay week after February 1st.

The North-East Engineering Bureau

The annual report of the North-East Engineering Bureau, which has just been issued, records a 30 per cent increase in membership in 1950. During the year the Bureau received 480 inquiries, which led to quotations being given in 364 cases, and to the placing of 120 orders. Analysing the inquiries received and the orders placed with member-firms, the Bureau comments in its report on the orders lost through material shortages and the ban on the non-essential uses of non-ferrous metals. It is most unfortunate at this stage in the national economy, the report says, that such a shortage should occur.

The introduction of the rearmament programme, the report continues, will tend to deteriorate the position still further and the Bureau is disturbed that twenty-two potential orders were lost through material shortages in the closing months of last year. It has also learned with considerable regret that some member-firms have been forced to dispense with the services of a number of employees on account of the materials position and that some others are contemplating having to work short time.

In another section of the report, the Bureau says it has emphasised for some time that, in order to secure full employment in the area, new industries should be established. That is being effected principally by large firms throughout the country starting up subsidiaries in the north-east. The report adds that member-firms are converting their works for the manufacture of new products, including weighing machines, bakery equipment and printing machinery. At present the Bureau is negotiating with an American firm which wishes to have its colour printing machines manufactured in this country.

The offices of the North-East Engineering Bureau are at Guildhall Chambers, 13, Sandhill, Newcastle-upon-Tyne. Mr. P. R. Walton is the general manager.

World Economic Report

A recent publication from the United Nations is World Economic Report, 1949–1950. It has been prepared by the U.N. Economic Affairs Department and is divided into three parts, the first part dealing with major developments in the "private enterprise" economies, the centrally-planned economies of Eastern Europe, the under-developed countries in Latin America and the Far East, and in Germany, Japan and China. The second part of the report discusses changes in the volume, value and direction of foreign trade and recent trends in international financial settlements, and the third part analyses the long-term and short-term aspects of the dollar shortage in international trade.

The report points out that, while the volume of goods produced in the world during the years 1949 and 1950, as well as the volume of international trade, rose to new heights, those developments did not take place without serious economic difficulties in a number of countries. Under-developed countries in general, it is stated, made little if any progress during those two years and the U.S.A. experienced a short-lived recession during 1949, from which it emerged to new peaks of production by the middle of 1950, although unemployment was still at its post-war peak. Moreover, the report notes, a large number of countries experienced serious foreign exchange difficulties during 1949, which brought on the imposition of new and more stringent import restrictions as well as currency devaluations in the autumn of that year.

Trade Disputes

There were 129 stoppages of work through industrial disputes reported to the Ministry of Labour as beginning in January, and four stoppages which had begun earlier were still in progress at some time in the month. In these 133 stoppages, the Ministry states, 24,100 workers were involved during January and 84,000 working days were lost. Sixty-four of the stoppages were in the coal-mining industry, involving 5900 men and accounting for a loss of 11,000 working days. There were twelve stoppages in the engineering industries in January. They involved 5600 workers and caused a loss of 15,000 working days. In January of last year 130 stoppages through disputes were reported, involving 22,800 workpeople and resulting in a loss of 65,000 working days.

Notes and Memoranda

Air and Water

NEW TANKER COMPANY.—The Anglo-Iranian Oil Company, Ltd., Common Brothers, Ltd., and Matheson and Co., Ltd., have formed a new company to own and operate oil tankers. Registered as a private limited company in London, it will be managed by Matheson and Co., Ltd., and Common Brothers, Ltd., the latter being responsible for the operation of the ships. Ten tankers, each of 16,000 tons deadweight, have been ordered, five to be built on the Clyde, two on the Tyne and three on the Wear. They will be chartered to the Anglo-Iranian Oil Company, Ltd.

FISHERIES RESEARCH VESSEL.—Funds under the Colonial Development and Welfare Act have made possible the building of the West African Fisheries Research vessel, which was launched last week from the yard of Hall Russell and Co., Ltd. The overall length is 117ft and the beam 25ft and the ship is powered by a diesel engine of 350 b.h.p. to give a speed of 12·5 knots. Besides the usual fishing equipment there is a small laboratory and accommodation for scientific officers. Based on Freetown, Sierra Leone, the vessel will be used by the staff attached to the laboratory of the West African Fisheries Research Institute, at Kissy, who expect to improve the fishing methods in West Africa.

Miscellanea

EXPORT LICENSING CONTROL.—Under an Order made by the Board of Trade and effective from March 3rd, export licences will be required for all destinations in respect of waste and worn-out cordage (paper-making materials), and bags and sacks of vegetable fibre, and for some destinations for particular types of high-pressure valves, compressors, blowers and fans, and sulphur burners and pyrites furnaces.

IRON AND STEEL DISTRIBUTION CHANGES.—The Minister of Supply has signed the Control of Iron and Steel (No. 80) Order, making certain amendments in the iron and steel distribution scheme. The Order enables the Ministry of Local Government and Planning to authorise the acquisition of steel sheets and tinplate and also deals with the price limit under the Small Quantities Exemption of Tinplate.

CYANIDE POTS.—A new type of cyanide pot, known as the "Wyprest," is now being supplied by Follsain-Wycliffe Foundries, Ltd., Lutterworth, Near Rugby. These pots are pressed from a layer of mild steel, to which is bonded a layer of nickel-chrome heat-resisting steel, approximately one-fifth of the total thickness. One of these pots, tested by B.S.A., Ltd., Birmingham, is stated to have lasted in service for 2800 hours.

DISCUSSION ON A NEW FACTORY.—The A.P.V. Company, Ltd., proposes to move its organisation to a new factory in the Crawley New Town, Sussex. Recently all the employees were given an opportunity to discuss the lay-out and organisation of the new works at a meeting, which took the form of a brains trust. Mr. P. W. Seligman, managing director of the company, acted as question master. The questions, most of which contained constructive suggestions, revealed a keen interest in the company's affairs on the part of the employees.

FELLOWSHIP OF THE CITY AND GUILDS INSTITUTE.—The Fellowship of the City and Guilds of London Institute has been conferred upon the following past students: Sir Harold L. Saunders, Comptroller-General of Patents, Designs and Trade Marks, Board of Trade; Mr. S. Scott-Hall, Principal Director of Technical Development (Air), Ministry of Supply; Dr. R. L. Smith-Rose, M.I.E.E., Director of Radio Research, Department of Scientific and Industrial Research, and Mr. M. T. Tudsbery, M.I.C.E., civil engineer to the British Broadcasting Corporation.

THE ROAD TRANSPORT ENGINEERS ANNUAL TOUR.—The Institute of Road Transport Engineers, has stated that arrangements for its annual tour for 1951 have now been completed. As previously announced, the tour will take the form of a survey of French goods and passenger service vehicle manufacture, transport maintenance and operation in the Paris area. The tour extends from Sunday, April 22, 1951, to the following Sunday, April 29th, and included in the itinerary are visits to the works of the principal road vehicle manufacturers, the maintenance depots and other road transport organisations in the Paris area.

INSTITUTION OF METALLURGISTS.—The next examinations for the Licentiateship and Associateship of the Institution of Metallurgists will be held from August 27th to September 3rd. Candidates must submit their applications for permission to enter the examinations before May 1st. Examinations for the Fellowship of the Institution will also be held from August 27th to September 3rd. Intending candidates should apply for permission to enter, submitting for the Council's approval a statement of the branch of metallurgy in which they offer themselves for examination. Forms of application can be obtained from the Registrar-Secretary of the Institution, 4, Grosvenor Gardens, London, S.W.1.

A BOOKLET ON MACHINING.—The booklet, "Machining," which is published by Deloro Stellite, Ltd., of Shirley, Birmingham, has now been printed in French. This booklet gives details of methods of grinding, tool-setting, a list of speeds and feeds for turning, milling, planing, &c., with details of relevant data. At the back of the book are listed standard shapes and sizes of "Stellite" toolbits, tool-tips, parting-off blades, tipped tools and milling blades; also a brief outline of Deloro "Stellite" hard steel drills, methods of operating and uses is given. Throughout the book metric sizes are shown with English equivalents.

ROYAL SHOW AT CAMBRIDGE.—The Royal Agricultural Society has announced that nineteen entries have been accepted for final judging in the Silver Medal competition for new implements at the forthcoming Royal Show at Cambridge. The entries include three implements deferred last year for further consideration. This year's judges for new implement awards are Mr. Roland Dudley and Mr. W. Newcome-Baker. The Society has also announced that Sir Roland Burke, who retired last year from the position of honorary director of the Show, has presented three perpetual trophies, one of which will be awarded for a new implement gaining a silver medal, provided the implement is considered to be of outstanding value to agriculture.

THE INCORPORATED PLANT ENGINEERS.—The annual dinner and dance of the London branch of the Incorporated Plant Engineers was held in London last Friday. In a speech toasting the institution and the London branch, Mr. H. J. Scott stressed the importance of plant engineers in all branches of industry. He said that their special function was to put new techniques into practice and to keep the wheels of industry running smoothly and efficiently. Mr. E. G. Phillips, the president, in replying to the toast, said that although the institution was young in years, it had a great part to play in the future of industry. Such an institution had been needed for at least twenty years in this country and now that it had been established its status was assured. He urged the members present to aim at and maintain a high standard and do all in their power to assist in furthering the growth of the institution.

"VACUUM."—We have recently received the first issue of a new quarterly journal, entitled *Vacuum*. That journal will concentrate on reporting progress in the field of vacuum research and vacuum engineering. It is addressed to the scientist who depends for his success on vacuum apparatus, to the industrialist who depends in his production on vacuum processing and to the specialist who, in turn, depends in his work on the results of such research and processes. We are informed by the publishers, W. Edwards and Co. (London), Ltd., Worsley Bridge Road, Lower Sydenham, London, S.E.26, that contributions will be accepted from all quarters and will be judged only by their technical value. The journal contains two sections—original contributions and abstracts. In this first issue Professor E. N. da C. Andrade, F.R.S., and Dr. R. J. C. Harris, the virus research worker, contribute articles. Subscription fees will be, British Isles, £1 5s., and abroad, £1 10s.

FILMS ON STEEL.—There was recently shown in London a 16mm film entitled "Sound Steel," which has been produced for Thos. Firth and John Brown, Ltd., Atlas Works, Sheffield, by the Brown-Firth Research Laboratories. It begins with details of steel making at the Atlas Works by the electric arc method, and emphasises the care which is exercised at every stage of manufacture, from melting to the finished product. The film also illustrates the production of solid and hollow forgings from all sizes of ingots made by the Siemens acid open-hearth process, and ends by demonstrating many of the present-day applications of the firm's special steels. Technical associations and other responsible bodies may obtain the use of the film, free of charge, by applying to Thos. Firth and John Brown, Ltd. On the same occasion there was shown a new film, entitled "River of Steel," which has been made for the British Iron and Steel Federation. It is a coloured cartoon film, using the Walt Disney technique, which demonstrates very ably how steel is an everyday necessity, not only directly but also, of course, in the manufacture of valuable exports.

Personal and Business

SIR HENRY WILSON SMITH, K.C.B., has been elected a director of Vacuum Oil Company, Ltd., Caxton House, Westminster, S.W.1.

MR. BRIAN REED states that his office address is now 2, Thames House, Queen Street Place, London, E.C.4 (telephone, Central 2981).

ROCKWELL MACHINE TOOL COMPANY, Ltd., states that Mr. C. G. Wareing has joined the sales staff at its northern office, 39, High Street, Stockport.

LIEUT.-COMMANDER H. DUDLEY HAYES, A.I.N.A., R.D., R.N.R., has been appointed assistant marine manager of the Sperry Gyroscope Company, Ltd., Brentford, Middlesex.

MR. PAUL ADORIAN, M.I.E.E., assistant managing director of Broadcast Relay Service, Ltd., has been appointed chairman of Redifon, Ltd., in succession to Sir Ronald Matthews.

THE BOARD OF TRADE announces that the office of the Central Price Regulation Committee has been moved to Clive House (7th Floor), Petty France, London, S.W.1 (telephone, Abbey 8010).

SIMON-CARVES, Ltd., Cheadle Heath, Stockport, has acquired the firm of Huntington, Heberlein and Co., Ltd., which will retain its name and continue to operate from its registered office at 114, Cromwell Road, London, S.W.7. Mr. R. B. Potter is chairman and Mr. J. P. V. Woollam, managing director, of Hunter, Heberlein and Co., Ltd.

Launches and Trial Trips

BRITISH WARRIOR, motor tanker; built by Joseph L. Thompson and Sons, Ltd., for the British Tanker Company, Ltd.; length overall 423ft, breadth 56ft, depth 30ft 1in, deadweight 8400 tons; Doxford oil engine, three cylinders, 600mm diameter by 2320mm combined stroke. Launch, February 22nd.

INSPECTOR NAVIGATION FOURCHON, trawler; built by Chantiers et Ateliers Augustin Normand for Gautier Frères; length between perpendiculars 32m, breadth moulded 7m, depth moulded 4·05m; single-acting, mechanical-injection, four-stroke M.A.N. diesel engine, six cylinders, 450 b.h.p. at 207 r.p.m. Launch, February 23rd.

CAPE ST. MARY, research trawler; built by Hall Russell and Co., Ltd., for the Crown Agents for the Colonies; length between perpendiculars 100ft, breadth moulded 25ft, depth moulded 12ft 6in; four-stroke, single-acting diesel engine, seven cylinders, 350 s.h.p. at 550 r.p.m., propeller r.p.m. 160, 11 knots. Launch, February 22nd.

CHANGCHOW, passenger-cargo vessel; built by Scott's Shipbuilding and Engineering Company, Ltd., for the China Navigation Company, Ltd.; length between perpendiculars 450ft, breadth moulded 62ft, depth moulded 35ft, deadweight 8910 tons; Scott-Doxford oil engine, six cylinders of 670mm diameter by 2320mm combined stroke, 6500 b.h.p. at 115 r.p.m., trial speed 17·5 knots. Trial, February 14th.

MTWARA, passenger and cargo coastal liner; built by Henry Robb, Ltd., for the British India Steam Navigation Company, Ltd.; length between perpendiculars 280ft, breadth moulded to upper deck 19ft 6in, gross tonnage 2629, deadweight 1815 tons on 16ft draught; passengers, 26 first-class, 48 second-class, 350 unberthed; two Kincaid-Polar, two-cycle, single-acting diesel engines, five cylinders, 2000 b.h.p. each at 250 r.p.m., loaded service speed 14 knots. Trial, February 13th.

BRITISH SPORTSMAN, motor tanker; built by Swan, Hunter and Wigham Richardson, Ltd., for the British Tanker Company, Ltd.; length overall 547ft., breadth moulded 69ft 6in, depth moulded 37ft 6in, deadweight 16,115 tons on a draught of 30ft; Wallsend-Doxford two-stroke oil engine, six cylinders, 670mm diameter by 2320mm combined stroke, 6400 b.h.p. at 115 r.p.m., two multi-tubular boilers; twenty-seven cargo tanks, two pump rooms, steam deck machinery and four 500-ton capacity cargo oil pumps. Trial, February 14th.

OIL PIPE-LINE TRANSPORT VEHICLES.—In the article, "Oil Pipe-Line Transport Vehicles," which appeared in our issue of February 16th, it was erroneously stated that the new oil pipe-line for the Iraq Petroleum Company is under construction by George Wimpey and Co., Ltd. We have been informed that this work is being carried out by the Arabian Bechtel Company.

British Patent Specifications

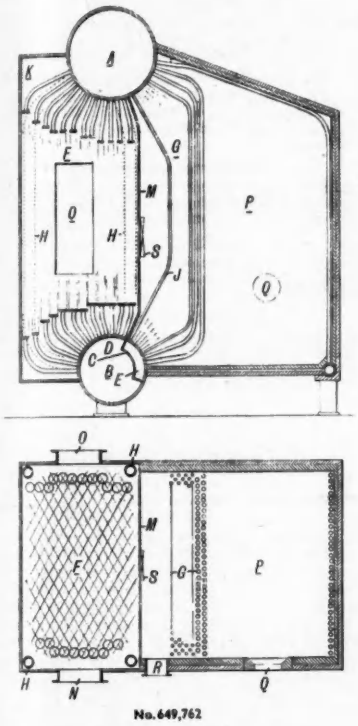
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 25, Southampton Buildings, Chancery Lane, W.C.2, 2s. each.

STEAM GENERATORS

649,762. February 15, 1946.—Improvements relating to Water-Tube Steam Boilers, Foster-Wheeler, Ltd., Aldwych House, Aldwych, London, W.C.2; William Sampson and Leonard James Culver, of the company's address.

In this water-tube boiler a single water or other liquid circulating system is common to two distinct heating chambers, one of which is devoted to the reception of so-called waste heat products and the other to combustion of fuel. The accompanying drawings show a diagrammatic sectional elevation of the boiler and a sectional plan. The boiler has the usual steam and water drum *A* in its upper part, and a water drum *B* at the bottom. The water drum is subdivided by a plate *C* to form two compartments *D* and *E*, which are sealed from each other. The water compartment *D* is connected to the drum by a set of tubes *F* and the compartment *E* is connected to the drum by a set of tubes *G*. Each of the two sets of tubes comprises risers and



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downcomers so that circulation through one set of tubes can occur independently of that through the other set. The downcomers are indicated at *H* and *J*. The two sets of tubes are arranged in two heating chambers *K* and *P*, which are separated by a wall *M* between the two drums. The heating chamber *K* has an inlet *N* through which waste heat gases can be passed into it. An outlet for these gases is provided at *O*. The heating chamber *P* contains an oil burner *Q* and has an outlet *R* for the combustion gases. Each side of the boiler functions like an ordinary water-tube boiler and as the water circulation and the heating on one side are entirely independent of those on the other, either side can be made to function efficiently irrespective of the conditions on the other side. A damper opening *S* by means of which gases can be passed from one chamber to the other is provided.—*January* 31, 1951.

HEAT EXCHANGERS

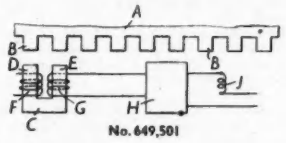
649,611. June 22, 1948.—Improvements in or relating to Thermal Regenerators, N.V. Philips' Gloeilampenfabrieken, of Emmasingel 29, Eindhoven, Holland.

This invention relates to thermal regenerators, more particularly for hot-gas air engines or cooling machines operating according to the reversed hot-gas engine principle. The thermal regenerator described comprises a filamentary non-metallic filling material, the filaments being metallised at their surfaces. The metallisation may consist of a thin layer of silver, or, alternatively, the filaments may be nickel, chrome or copper-plated. According to an example quoted a filament of quartz wool 10 microns thick, is coated in any suitable manner with a metal layer 5 microns thick, so that the diameter of the filament becomes 20 microns—a very suitable size for use as a regenerator filling material. A drawing given by way of an example in the specification shows a quantity of metallised quartz wool set between two pieces of wire cloth fixed in a regenerator housing.—*January* 31, 1951.

ELECTRICAL ENGINEERING

649,501. March 14, 1945.—Improvements in or relating to Electric Control Apparatus, The Igranic Electric Company, Ltd., of Elstow Road, Bedford; John Russell Taylor, of 2, Beresford Road, Bedford, and John Melvin Bedford, of 10, Lancaster Avenue, Bedford.

Referring to the drawing *A* is a toothed rack with rectangular teeth *B*, and there is an iron core member *C* in the form of a rectangular U. The space between adjacent teeth of the rack may be the same as the space between the two limbs *D* and *E* of the core member *C*, and the parts are so disposed that, when the rack moves longitudinally the ends of the teeth move successively past the core member. One limb of the core member is wound with a direct current exciting winding *F*. The other limb is wound with a search coil *G* which supplies a thermionic amplifier *H* which, in turn, supplies the winding *J* of a relay. As the ends of the teeth move past the ends of the limbs of the core member, the reluctance of the magnetic circuit varies from



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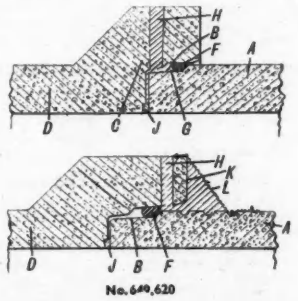
a minimum (when the ends of the limbs *D* and *E* are opposite to teeth *B*) to a maximum, when the ends of the teeth are opposite to spaces. Therefore, the magnetic flux in the magnetic circuit will alternately rise and fall and an alternating potential will accordingly be induced in the search coil G. One half wave of this alternating potential is amplified by the thermionic amplifier *H* and a unidirectional pulsating current is supplied to the relay winding *J*. The amplifier incorporates a reservoir condenser for maintaining sufficient current in the relay winding during the fall of the pulsating voltage. Thus a continuous and relatively smooth direct current is delivered. So long as the rack is in motion, the relay is energised, and immediately the rack or wheel stops, the relay is de-energised. In a modification of the arrangement the teeth, instead of being formed on a longitudinally movable rack, are formed on the circumferential periphery of a rotatable wheel. In a further modification, instead of the limb *D* being wound with the exciting winding, it is made as a permanent magnet.—*January* 31, 1951.

MISCELLANEOUS

649,620. July 9, 1948.—Improvements in or relating to Pipes of the Socket and Spigot Type, The Stanton Ironworks Company, Ltd., of Stanton-by-Dale, near Nottingham, and Frederick Benjamin Cornelius, of the company's address.

The main object of this invention is to provide an improved form of joint for sealing two pipe sections together. The accompanying drawings



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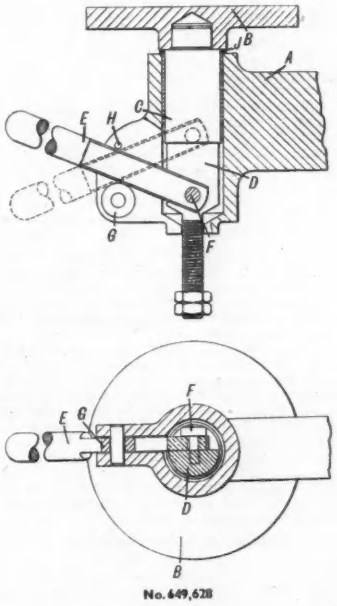
show a longitudinal half-sectional view of a joint between two pipes and of a modified arrangement. As shown in the upper view, the spigot end of a pipe section *A* is slightly tapered at the end *B*, which fits into the socket *C* of another section *D*. A stout ring of rubber or other compressible material *F* is fitted over the tapered part of the spigot, and the spigot, together with the rubber ring, is then forced into the socket of the adjacent pipe section, which is suitably shaped internally so that the space between the socket and spigot is a wedge-shaped annular cavity *G*. The jointing ring rolls towards the narrower end of this cavity, and forms a seal between the two pipe sections. A grouting of cement and sand is then poured into the cavity to form a double seal. For this purpose a grout hole *H* is provided in the socket wall and an air hole permits the escape of air from the annular space between the two pipe sections. In order to prevent this grout from passing into the bore of the pipe-line, a keyed recess *J* is formed in the bore of the pipe *D* at the socket end. Into this recess, when the two pipes have been joined with the rubber ring in position and before the grout is poured in, there is introduced a cement-sand composition or other suitable material which forms a sealing ring and effectively prevents the leakage of the grout from the cavity *G* into the bore of the pipes. Alternatively, the keyed recess may be fitted with a ring composed of bituminous material. In a modification of the invention shown in the lower view, the joint ring is on the inside of the grout hole *H* instead of on the outside, the grout being poured round the outer end *K* of the socket in front of the ring. To enable this to be effected a bag *L* of hessian or other suitable material is provided consisting of a strip of hessian into which is woven suitable wires for fixing purposes. By means of this invention it is claimed that a very effective joint is produced which may be used on all pipe-lines employed for conveying water, sewage or other liquids, either by gravity or under pressure.—*January* 31, 1951.

MACHINE TOOLS

649,828. December 3, 1948.—Mechanism for Raising and Lowering the Worktables of Machine Tools such as Drilling and Tapping Machines, Engineering Products, Ltd., Glenbrook Works, Littlers Close, Colliers Wood, London, S.W.19, and Leslie Frank Standen, of the company's address.

The accompanying drawing shows a sectional elevation and an inverted plan partly in section. The table support *A* extends from the machine frame. The worktable *B* has a spigot *C* and can slide vertically in a bore in the support. The spigot has a part *D* of reduced diameter milled



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flat to a depth of half the diameter. An actuating lever *E* is pivoted to the flat of the spigot by a shoulder screw *F*, and a fulcrum for the lever is provided by a hardened roller *G*. The lever *E* fulcrums on the roller when its outer end is depressed to raise the worktable to present a workpiece to the tool carried by the machine spindle. Return of the table is effected by gravity, but a return spring may be fitted if desired. A small pin *H* is fixed in the cheeks to support and limit the vertical travel of the lever. The upward stroke of the table may be adjusted by means of lock nuts on the lower end of the spigot. The lowest position of the table is determined by the contact between the support, a felt washer *J* and the boss of the table.—*January* 31, 1951.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office on, or before, the morning of the Monday of the week preceding the meetings. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

Association of Supervising Electrical Engineers

Mon., Mar. 5th.—SHEFFIELD BRANCH: Royal Victoria Hotel, Sheffield, "Electricity in the Brewing Industry," S. Biggin, 7.30 p.m.——N.E. LONDON BRANCH: Angel Hotel, Ilford, "Electrical Suppression of Interference," G. L. Stephens, 8 p.m.

Tues., Mar. 6th.—W. LONDON BRANCH: Town Hall, Hammersmith, "Power Plant Installations," W. F. Parker, 7.30 p.m.

Wed., Mar. 7th.—YORK BRANCH: Royal Station Hotel, York, "The Electrical Loading of a Fabrication Shop," J. J. Skeldon, 8 p.m.

Fri., Mar. 9th.—BRISTOL BRANCH: Grand Hotel, Bristol, "Floodlighting," R. S. Hazell, 7.30 p.m.——CREWE BRANCH: Crewe Arms Hotel, Crewe, "Illumination Design," S. D. Pryor, 7.30 p.m.——NOTTINGHAM BRANCH: Electricity Showrooms, Smithy Row, Nottingham, "Automatic Sequence Control of Conveyors and Belt Protection," T. A. Peat, 7.30 p.m.

Belfast Association of Engineers

Wed., Mar. 7th.—College of Technology, Belfast, film evening, 7 p.m.

British Institute of Management

Tues., Mar. 6th.—Management House, 8, Hill Street, London, W.1, "Problems of Decentralisation in a Large-Scale Undertaking," Sir Henry Self, 5.30 p.m.

Electric Railway Society

Sat., Mar. 3rd.—Fred Tallant Hall, Drummond Street, London, N.W.1, "Electrification in the Manchester Area," R. K. Kirkland, 3 p.m.

Engineers' Guild

Thurs., Mar. 8th.—METROPOLITAN BRANCH: Caxton Hall, Caxton Street, Westminster, S.W.1, discussion on "The Engineer and the Public," introduced by H. Nimmo, 6 p.m.

Illuminating Engineering Society

To-day, Mar. 2nd.—BATH AND BRISTOL CENTRE: S.W. Electricity Board Showrooms, Bath, "Illumination and Illusion," P. Hartill, 7 p.m.

Mon., Mar. 5th.—LEEDS CENTRE: Lighting Service Bureau, 24, Aire Street, Leeds, 1, "The Lighting of Departmental Stores," A. W. Jervis, 7 p.m.——SHEFFIELD CENTRE: The University, Weston Bank, Sheffield, 10, "Railway Light Signalling System" G. G. F. Halliwell, 6 p.m.

Wed., Mar. 7th.—NEWCASTLE CENTRE: Minor Durrant Hall, Oxford Street, Newcastle-upon-Tyne, 1, "The Design of Lighting Fittings," W. R. Stevens, 6.15 p.m.——HUDDERSFIELD GROUP: Electricity Showrooms, Market Street, Huddersfield, "Electric Lighting—A Contractor's Viewpoint," J. Ashmore, 7.15 p.m.——SWANSEA GROUP: 4, Northampton Gardens, Swansea, "Underground Lighting in British Coal Mines," D. A. Strachan, 5.45 p.m.

Thurs., Mar. 8th.—CARDIFF CENTRE: School of Mines, Treforest, "Underground Lighting in British Coal Mines," D. A. Strachan, 5.45 p.m.——LEICESTER CENTRE: E. Midlands Electricity Board, Charles Street, Leicester, "Hospital Lighting," M. W. Peirce and D. J. Reed, 6.30 p.m.

Fri., Mar. 9th.—BIRMINGHAM CENTRE: Imperial Hotel, Temple Street, Birmingham, annual general meeting, "Light and Vision," H. C. Weston, 6 p.m.

Incorporated Plant Engineers

Mon., Mar. 5th.—LONDON BRANCH: Royal Society of Arts, John Adam Street, Adelphi, W.C.2, annual general meeting; film, "Prelude to Power," 7 p.m.——DUNDEE BRANCH: Mather Hotel, Dundee, annual general meeting, 7.30 p.m.

Tues., Mar. 6th.—GLASGOW BRANCH: Engineering Centre, 351, Sauchiehall Street, Glasgow, annual general meeting and open discussion, 7 p.m.——KENT BRANCH: Technical College, Maidstone, annual general meeting, 7 p.m.——S. WALES BRANCH: Grand Hotel, Westgate Street, Cardiff, "Safety Precautions," A. H. Long, 7.30 p.m.

Thurs., Mar. 8th.—KENT BRANCH: Technical College, Maidstone, "The Making of Paper," W. T. Armstrong, 7 p.m.——NEWCASTLE-UPON-TYNE BRANCH: Royal Turk's Head Hotel, Grey Street, Newcastle-upon-Tyne, annual general meeting, 7.30 p.m.

Institute of British Foundrymen

Mon., Mar. 5th.—SHEFFIELD BRANCH: Royal Victoria Station Hotel, Sheffield, "The Assessment and Interpretation of Foundry Controls," J. W. Colton, 7.30 p.m.

Wed., Mar. 7th.—BIRMINGHAM AND W. MIDLANDS STUDENTS' SECTION: Chance Technical College, Smethwick, "A Comparison of British and Foreign Foundry Practice," H. T. Angus and W. B. Parkes, 7.15 p.m.——LANCASHIRE BRANCH: Engineers' Club, Albert Square, Manchester, "Cylinder Moulding," D. Redfern, 7 p.m.

Thurs., Mar. 8th.—LINCOLNSHIRE BRANCH: Technical College, Lincoln, open meeting, discussion on foundry problems, 7.15 p.m.——BURNLEY SECTION: Municipal Technical College, Ormerod Road, Burnley, annual general meeting, "Rammed Linings," J. Jackson, 7.30 p.m.

Institute of Industrial Supervisors

Wed., Mar. 7th.—W. BROMWICH SECTION: Grammar School, West Bromwich, "The Hawthorne Investigation," J. S. Hudson, 7.45 p.m.

Thurs., Mar. 8th.—LEEDS SECTION: Great Northern Hotel, Leeds, "Some Aspects of Materials Handling in Industry in the U.S.A.," E. G. Taylor, 7.30 p.m.

Institute of Marine Engineers

Tues., Mar. 6th.—Technical Institute, Sheerness, "Welding in Ship Repair Work," J. W. Coulthard, 6.15 p.m.

Thurs., Mar. 8th.—Borough Polytechnic, London, S.E.1, "Refrigeration at Sea," R. R. Strachan, 6.30 p.m.

Institute of Petroleum

Wed., Mar. 7th.—Manson House, 26, Portland Place, W.1, films, "As Old as the Hills," "Pipe-line in Arabia (Tapline)," "Steam," 5.30 p.m.

Institute of Road Transport Engineers

Fri., Mar. 9th.—S. WALES GROUP: S. Wales Institute of Engineers, Park Place, Cardiff, open discussion meeting, 7 p.m.

Institution of Civil Engineers

Tues., Mar. 6th.—Great George Street, Westminster, S.W.1, "Methods of Effecting Economy in Track Maintenance and Renewal," E. C. Cookson, 5.30 p.m.

Thurs., Mar. 8th.—MIDLANDS ASSOCIATION: James Watt Memorial Institute, Great Charles Street, Birmingham, "Sewage Purification Works in the States," M. R. Vincent Davies, 6 p.m.

Institution of Electrical Engineers

To-day, Mar. 2nd.—N.E. STUDENTS' SECTION: King's College, Newcastle-upon-Tyne, "The Schlieren System," B. Berger, 6.30 p.m.

Sat., Mar. 3rd.—N. MIDLAND STUDENTS' SECTION: Technical College, Great Horton Road, Bradford, "The Van de Graffe D.C. Generator," J. A. Henry, 2.30 p.m.

Mon., Mar. 5th.—Savoy Place, Victoria Embankment, W.C.2, discussion on "The Best Means of Explaining the Internal Operation of Electronic Valves," opened by A. F. H. Thomson, 6 p.m.——N.E. CENTRE: King's College, Newcastle-upon-Tyne, "The Nervous System as a Communication Network," J. A. V. Bates, 6.15 p.m.——S. MIDLAND CENTRE: James Watt Memorial Institute, Great Charles Street, Birmingham, discussion, "Engineering—Financial Problems Arising in the Electricity Supply Industry," D. H. Kendon, 6 p.m.

Tues., Mar. 6th.—N. MIDLAND CENTRE: British Electricity Authority, 1, Whitehall Road, Leeds, 1, "The Performance of the British Grid System in Thunderstorms," J. S. Forrest, 6.30 p.m.

Wed., Mar. 7th.—RADIO SECTION: Savoy Place, Victoria Embankment, W.C.2, "Design Considerations for a Radiotelegraph Receiving System" J. D. Holland, 5.30 p.m.

Institution of Engineering Inspection

Tues., Mar. 6th.—S.W. BRANCH: Grand Hotel, Bristol, "Some Aspects of Industrial Statistics," G. Young, 7.30 p.m.

Wed., Mar. 7th.—BIRMINGHAM BRANCH: Chamber of Commerce, Birmingham, "Manufacture of Seamless Steel Tubes," J. Jenkin, 7.30 p.m.

Institution of Heating and Ventilating Engineers

Tues., Mar. 6th.—N.E. COAST BRANCH: Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, "Air Conditioning," B. W. R. Hickmott, 6.30 p.m.

Wed., Mar. 7th.—E. MIDLANDS BRANCH: Victoria Station Hotel, Nottingham, installation of Chairman and papers for John Hughes Prize, 6.30 p.m.

Institution of Mechanical Engineers

To-day, Mar. 2nd.—Storey's Gate, St. James's Park, S.W.1, "The Training of Engineers for the Chemical Industry," W. F. Carey, 5.30 p.m.——N.E. BRANCH, GRADUATES' SECTION: King's College, Newcastle-upon-Tyne, "The Schlieren System" B. Berger, 6.30 p.m.

Mon., Mar. 5th.—N.E. BRANCH: Neville Hall, Westgate Road, Newcastle-upon-Tyne, "The Design and Development of the Twin Centaurus Power Plant for the 'Brabazon' Aircraft," J. L. Norton, 6 p.m.

Tues., Mar. 6th.—COVENTRY A.D. CENTRE: Craven Arms Hotel, High Street, Coventry, annual meeting, 7 p.m.

Thurs., Mar. 8th.—Engineers' Club, Albert Square, Manchester, discussion on "Springs," opened by J. A. Roberts, 6.45 p.m.——YORKSHIRE BRANCH: The University, Leeds, "Corrosion-Resisting Steels," J. A. McWilliam, 7 p.m.

Fri., Mar. 9th.—N.E. BRANCH, GRADUATES' SECTION: Head, Wrightson and Co., Ltd., Eaglescliffe Foundry, Yarm Road, Stockton-on-Tees, "The Manufacture of Mineral-Insulated, Copper-Covered Cables—Some Engineering Aspects," G. P. Fyson, 7 p.m.——Storey's Gate, St. James's Park, S.W.1, "Further Mechanical Aids for the Foundry," A. S. Beech, 5.30 p.m.

Institution of Post Office Electrical Engineers

Tues., Mar. 6th.—Institution of Electrical Engineers' Savoy Place, Victoria Embankment, W.C.2, "The Provision and Maintenance of Long-Distance Circuits London Trunk Transmission Control," E. H. Jeynes and J. E. Isherwood, 5 p.m.

Institution of Production Engineers

To-day, Mar. 2nd.—W. WALES SUB-SECTION: Central Library, Alexandra Road, Swansea, "Social Function of Industry," A. Roberts, 7.30 p.m.

Tues., Mar. 6th.—READING SUB-SECTION: Transport Equipment (Thornycroft), Ltd., Basingstoke, "The Manufacture and Testing of Gas Turbine Engines," E. A. Rodocanachi, 7.15 p.m.

Wed., Mar. 7th.—NOTTINGHAM SECTION: Victoria Station Hotel, Milton Street, Nottingham, annual general meeting, 7 p.m.——S. ESSEX SUB-SECTION: Conservative Club, Ilford, "Budgetary Control," 7.30 p.m.——WOLVERHAMPTON SECTION: W. Midland Gas Board, Darlington Street, Wolverhampton, "Industrial Maintenance of Machines," R. M. Buckle, 7 p.m.

Thurs., Mar. 8th.—LUTON GRADUATE SECTION: The Library, Williamson Street, Luton, annual general meeting, 7.30 p.m.——SOUTHERN SECTION: Polygon Hotel, Southampton, "Nuclear Power: a résumé of Development of Atomic Power," W. L. Mirehouse 7 p.m.——WESTERN SECTION: T. H. and J. Daniels, Ltd., Stroud, "Foremanship," A. P. Young, 7.30 p.m.

Institution of Structural Engineers

To-day, Mar. 2nd.—WESTERN COUNTIES BRANCH: College of Technology, Bristol, "Light-Gauge Structural Steel Sections," F. W. L. Heathcote and A. H. Chilver, 6.15 p.m.

Thurs., Mar. 8th.—11, Upper Belgrave Street, London, S.W.1, "Special Treatments for Portland Cement Concrete," C. L. a'Court, 6 p.m.

Institution of Works Managers

To-day, Mar. 2nd.—NOTTS AND DERBY BRANCH: Midland Hotel, Derby, "Is Management an Art or a Science?" J. Ayres, 7.30 p.m.

Junior Institution of Engineers

To-day, Mar. 2nd.—39, Victoria Street, S.W.1, films on "Foundry Practice," introduced by A. S. Ladley, 6.30 p.m.

Mon., Mar. 5th.—N.W. SECTION: Geographical Society, 16, St. Mary's Parsonage, Manchester, "Marine Radar," T. R. Goode, 7 p.m.

Wed., Mar. 7th.—MIDLAND SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, "Research and the Marine Engineer," D. J. Hoare, 7 p.m.

Fri., Mar. 9th.—39, Victoria Street, London, S.W.1, "Glass, Light and Designs," J. G. Holmes, 6.30 p.m.

Liverpool Engineering Society

Wed., Mar. 7th.—24, Dale Street, Liverpool, "The Manufacture of Ships' Propellers," F. J. Tector, 6 p.m.

Liverpool Metallurgical Society

Thurs., Mar. 8th.—Electricity Service Centre, Whitechapel, Liverpool, "Atomic Structure and the Hardness of Metals," Hugh O'Neill, 7 p.m.

North-East Coast Institution of Engineers and Shipbuilders

Fri., Mar. 9th.—Neville Hall, Newcastle-upon-Tyne, "The Application of Statistical Methods to the Analysis of Service Performance Data," J. W. Bonebakker, 6.15 p.m.

Royal Aeronautical Society

Wed., Mar. 7th.—Technical College, Corporation Street, Preston, "The Development of Air Operations in the 1914–1918 War," Norman Macmillan, 7.30 p.m.

Society of Engineers

Mon., Mar. 5th.—Geological Society, Burlington House, London, W.1, "Metallic Arc Welding," B. W. Silverwood, 5.30 p.m.

Women's Engineering Society

Wed., Mar. 7th.—LONDON BRANCH: 35, Grosvenor Place, S.W.1, "British Railways—The Permanent Way," L. G. B. Roch, 7 p.m.

Technical Reports

"*Investigations on Building Fires. Part IV: Fire Resistance of Timber Doors.*" National Building Studies Technical Paper No. 6. London: H.M. Stationery Office. Price 1s.—The damage done by fires in buildings can be limited if doors are made fire-resistant enough to delay the spread of the fire to rooms other than that in which it started. A resistance giving a delay of only half-an-hour is often enough to enable a fire brigade to obtain control of the outbreak before other parts of the building are affected. An investigation carried out by the Building Research Station into methods of improving the fire-resistance of existing doors and of designing new doors, which will resist the spread of fire, is described in this report. Economical ways were found of using plasterboard or thin metal sheathing to make existing doors more resistant and two new designs for inexpensive doors were produced. Tests carried out on various types of doors showed that there is little difference in the fire-resisting qualities shown by hardwoods and softwoods.

The Protection of Buildings and Timber Against Termites. Forest Products Research Bulletin No. 24. London: H.M. Stationery Office. Price 1s. 9d.—Before the publication of this report no concise summary of information on the prevention and control of infestation of buildings and building materials by termites was available. The report is a simple manual written for the practical builder, architect, forest officer and others concerned with the problem. It has been planned to stimulate interest in the habits of termites. It describes the biology of the insects, the organisation of their colonies, how they swarm and their mode of attack. It then deals with the general protective measures, methods of eradication and the natural resistance and preservative treatment of timber. One of the chapters describes the construction of buildings incorporating termite barriers of various kinds. Lists of resistant timbers in the different colonies are given and there are notes on how to collect termites and despatch them for identification.